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LETTER FROM THE EDITOR

Acta Oto-Laryngologica has now increased its number of foreign collaborators, partly from those countries already represented and partly from others not hitherto represented. The main purpose of this extension is to gain wider circulation and an intensified exchange of views between colleagues in our speciality, independent of race and language.

On account of the large number of acceptable papers received, we shall publish two volumes during 1962 (each volume consisting of six numbers). As usual a number of supplements will be distributed with these volumes, free of charge.

Stockholm, July 1962

PAUL FRENCKNER

EFFECTS OF SURGICAL STRESS ON THYROID FUNCTION IN MAN

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The influence of surgical stress on the human thyroid after head and neck operations was studied by measurements of the early accumulation of radioiodide in the thyroid and by determinations of PBI^{131} and PBI levels before and after operation Studying 21 patients it could be shown that after severe surgical stress the I^{131} uptake in the thyroid was decreased up to 18 hours After slighter operations under local or general anesthesia the I^{131} uptake was unchanged during the first six hours but increased thereafter from the 1st 7th postoperative day with its maximum on the 3rd and 4th days

The PBI^{131} levels showed an approximately daily increase of about 0 013 % with no significant difference between 14 operated and 11 control cases during the 11 days of observation In the operated group however a rapid secretion of PBI^{131} after surgical trauma could be observed followed by decreased hormone secretion The PBI^{131} level after the first four postoperative hours comprised half the total increase of the following two days The difference from the controls was not significant but this may be because no patient underwent severe operation Nor was any difference observed between patients operated under local and under general anesthesia

The PBI levels of 16 operated patients showed a slight decrease 6 12 days after operation but no difference between cases with local and with general anesthesia

The influence of surgical stress on thyroid function has been the subject of many studies Contradictory results have been reported in animals and humans depending on differences in experimental conditions

Most investigators report a marked decrease of

1 the radioiodide accumulation in the thyroid (van Middlesworth & Berry 1951 Hamolsky *et al* 1951)
2 the release of thyroid hormone measured as protein bound radioiodine in the serum (PBI^{131}) (Brown Grant 1957) and
3 the protein bound stable iodine in the serum (PBI) (Bondy & Hagewood 1952 Peters & Man 1955)

Other investigators have found unchanged (Engstrom & Markardt 1954) or increased radioiodide uptake 1 3 6 and 24 hours after operation (Goldenberg *et al* 1954 1955)

Increased hormone release (PBI^{131}) was observed by Shipley & McIntre (1954) 24–48 hours after operation. Goldenberg *et al.* (1955) saw immediately after the operation a marked decrease of I^{131} in the thyroid, suggesting a sudden release of hormone from the thyroid. Franksson *et al.* (1959) reported in some cases a marked increase of PBI^{131} levels 24–48 hours after operation followed by a period of about five days during which the average daily increase of PBI^{131} was smaller than in the control cases.

Schwartz & Roberts (1957) found an increase of PBI levels within the first two hours after operation and a decrease below the preoperative level within 24 hours. Engstrom & Markardt (1954) and Goldenberg *et al.* (1954, 1955) did not see any significant differences at all. Because of the variations in these reports the following investigation was performed to study the influence of surgical stress on the thyroid function in man.

MATERIAL AND METHODS

The investigation was carried out on euthyroid patients, operated for head and neck diseases. Patients with bad general condition, heart or renal diseases and those who had received drugs that influence the thyroid function were not included. Skin disinfection solutions containing iodine were avoided before, during and after operation.

The thyroid function was checked by determination of (1) the early I^{132} uptake in the thyroid, (2) PBI^{131} and (3) PBI.

The early uptake of radioiodide was measured in 21 patients before, immediately after and 2, 4, 6 hours and 1, 2, 3, 4, 5 and 7 days after operation. Six patients were operated under local anesthesia (Xylocain with Adrenaline) and 15 patients under general anesthesia (Narcotal, N_2O and Celocurin).

The following operations were performed under local anesthesia: three otosclerosis and three radical operations of the ear. Under general anesthesia the following operations were performed: three parotidectomies, two neck dissections, one sequestrotomy in the jaw, three extirpations of hypopharynx diverticles, two progeni operations, two otosclerosis operations, one partial resection of the palatinum, one extirpation of an adamantinoma. The ages of the cases operated ranged from 22–74 years with an average of 43 years.

The early accumulation of radioiodide in the thyroid was measured according to Larsson & Jonsson (1955). The counting rate over the thyroid region was measured continuously. The difference between the counting rates at 1 and 11 minutes is expressed as a percentage of the counting rates from a standard solution and is called the *H* value (*H*%). This technique provided a quick test for the accumulation rate of radioiodide in the thyroid and is very useful for repeated measurements at short intervals in the same patient. For repeated intravenous tests the short lived I^{132} was used, which was separated from Te^{132} by the method described by Stang *et al.* (1957). The *H* values after the operation are expressed as the difference from the values before operation and are called *H* diff %.

PBI[131] was estimated in 14 patients. Seven of them were operated under local anesthesia (two otosclerosis operations, three operations on the ear, two sequestrotomies). Seven patients were operated under general anesthesia (one progeni operation, one fracture in the zygomaticus bone, two neck dissections, two oesophagus diverticles). The average age of the operated patients was 38 years (range 21–62).

PBI[131] levels were also studied in 11 control cases with an average age of 50 years (range 42–72).

Before any treatment was started the patients received a labelled dose of 100 microcurie I^{131} orally three days before the operation. From the second day after the administration of I^{131} (24 hours before operation) PBI[131] was estimated daily for up to 11 days after operation. The PBI[131] was determined by the technique of Goodwin *et al.* (1951). The concentration of PBI[131] was expressed as a percentage of the administered dose per litre plasma.

In 16 patients the PBI level was determined before and 1, 3, 6 and 12 days after operation, in five patients also four hours after operation. The average age of these patients was 45 years (range 25–61). The PBI level was determined by the method of Barker *et al.* (1951).

Conventional statistical methods were used for the determination of the standard error of the mean and the probability value. A difference was said to be almost significant (*) if $p \leq 0.05$, significant (**) if $p < 0.01$ and highly significant (***) if $p \leq 0.001$.

RESULTS

The results of the measurements of the early I^{131} uptake in the thyroid are given in Table 1. The *H* values after the operation are expressed as the difference from the preoperative values.

There is a significant difference between two groups of patients operated under general anesthesia. Nine of them had a slight surgical trauma and the average duration for anesthesia in this group was 1½ hours. The other six experienced more severe surgical stress and the average time for anesthesia was 2½ hours.

In the second group the radioiodide uptake was depressed below the preoperative level 48 hours after operation (Fig. 1, Table 1). In the other group and in patients who were operated under local anesthesia no decrease of the thyroid uptake could be observed; on the other hand, from the 2nd–7th postoperative day there was a significant increase of the thyroid uptake in these groups (Fig. 1, Table 1).

The difference between the I^{131} uptake in the thyroid after the two different types of surgical stress is significant from the 1st to the 4th postoperative day (Table 1, Fig. 1).

The result of the PBI[131] determinations is shown in Table 2. The values are expressed as the differences from the values on the day of operation, i.e. 72 hours after administration of radioiodide. Comparison between the PBI[131]

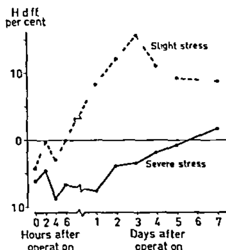


Fig. 1. Diagram of the early I^{131} accumulation in the thyroid after operation. The values are expressed as the difference from the preoperative values. Compare Table 1.

levels of 14 operated patients and 11 control cases showed a nearly identical approximately linear increase of the levels in both groups during 14 days of observation (Table 2, Fig. 2). No difference could be observed between the patients operated under local and under general anesthesia.

The increase in the concentration of PBI^{131} during the first four postoperative hours comprised about two thirds of the total increase during the first postoperative day and was twice as much as the total increase during the second day; this indicates a rapid secretion of the stored PBI^{131} in the thyroid after surgical trauma.

Table 3 shows the results of PBI determinations in 16 patients. The postoperative values are expressed as the differences from the values before operation. Four hours after operation it seems there was a slight increase and 6–12 days after operation a slight decrease of the levels, but neither is significant. Because of the small number of the patients the result must be regarded as uncertain. No difference was observed between the levels of patients operated under general and under local anesthesia.

DISCUSSION

Severe surgical stress decreased thyroidal radioiodide accumulation and hormone release from the gland in euthyroid subjects. Similar effects have been noted after the administration of ACTH and cortisone and it had been assumed that the depression of thyroid function after surgical stress mainly depends on the increase of these hormones.

ACTH and cortisone have been reported as reducing the I^{131} uptake in the thyroid (Hill *et al.* 1950), the release of hormone (Brown-Grant *et al.* 1954) and the level of protein bound stable iodine (Hill *et al.* 1950). It has been

... after operations under local and general anesthesia

Group 1 cases with light surgical stress Group 2 cases with severe surgical stress

Statistics on (1) sign of diff from zero in each group individually and (2) sign of diff between both groups Postoperative values are expressed as the difference ($H°_a$ diff) from the preoperative values ($H°_a$) Compare Fig 1

	Before operation ($H°_a$)	After operation ($H°_a$ diff)									
		Immediately after operation	2 hr	4 hr	6 hr	1 day	2 days	3 days	4 days	5 days	7 days
A Local anesthesia											
n	6	6	6	6	6	6	4	3	5	6	—
$\bar{x}$	+1.21	0.58	0.15	0.54	+0.20	+0.65	+0.81	+1.63	+1.17	+0.80	—
$s_{\bar{x}}$	—	0.125	0.323	0.258	0.300	0.323	0.183	0.420	0.350	0.570	—
B General anesthesia											
n	9	1	8	8	8	9	8	9	9	8	5
$\bar{x}$	+1.15	0.22	0.01	0.17	0.21	+0.94	+1.11	+1.51	+1.05	+1.02	+0.87
$s_{\bar{x}}$		0.520	0.317	0.301	0.388	0.571	0.155	0.309	0.285	0.319	0.108
Group 1 A + B											
n	15	10	14	14	14	15	12	12	14	14	5
$\bar{x}$	1.35	0.14	0.02	0.30	0.01	+0.82	+1.21	+1.55	+1.10	+0.92	+0.87
$s_{\bar{x}}$	—	0.118	0.235	0.203	0.256	0.332	0.112	0.287	0.214	0.295	0.168
Sign of diff from zero											
t		1.201	0.070	1.481	0.028	2.265	3.538	5.402	5.117	3.120	5.202
p				—	—	*	**	***	***	**	**
Group 2											
n	6	1	1	1	6	6	6	5	6	6	1
$\bar{x}$	+1.75	0.12	0.18	0.88	0.67	−0.77	0.11	0.35	0.19	0.08	+0.10
$s_{\bar{x}}$	—	0.623	0.577	0.500	0.357	0.201	0.154	0.253	0.171	0.227	0.028
Sign of diff from zero											
t		0.986	0.800	1.711	1.877	2.917	2.532	1.351	0.101	0.152	5.054
p		—			—	*	*				
Sign of diff between groups 1 + 2											

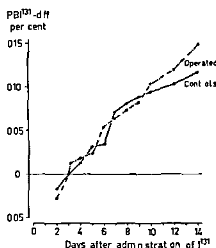


FIG 2 Diagram of PBI[131] levels in 14 operated and 11 control cases All values are expressed as the difference between the values on the day of operation and 72 hours after administration of 100 μC I[131] respectively Compare Table 2

shown that ACTH probably acts via cortisone and that its depressive effect on thyroid function cannot be observed in adrenalectomized animals (Brown-Grant 1956 Harris & Woods, 1957) On the other hand cortisone withdrawal in adrenalectomized patients increased the thyroidal uptake of I[131] and PBI and replacement of cortisone was followed by decrease of both (Einhorn & Franksson 1961) Thyroid hormones also influence the adrenal function

TABLE 2 *Level of protein bound radioiodine in the serum (PBI[131]) in 14 operated and 11 control cases*

The values are expressed as the difference between the values on the day of operation and 72 hours after administration of 100 μC I[131] respectively Compare Fig 2

	PBI 131 / % (diff between day of operation)											
	Days after administration of I131											
	2	3 (day of operation)	4 hr after operation	4	5	6	7	8	9	10	12	14
Operated cases												
n	13		14	14	14	14	14	13	13	14	11	1[illegible]
x	0 028	—	+0 012	+0 019	+0 024	+0 054	+0 064	+0 073	+0 092	+0 105	+0 11[illegible]	+0 1[illegible]
S E	0 025	—	0 006	0 013	0 014	0 014	0 011	0 013	0 017	0 016	0 020	[illegible]
Control cases												
n	11			10	11	10	10	8	10	10	11	11
x	0 017	—	—	+0 013	+0 032	+0 035	+0 071	+0 081	+0 089	+0 0[illegible]	+0 102	+0 11[illegible]
S E	0 001	—	—	0 005	0 009	0 009	0 020	0 010	0 02[illegible]	0 027	0 0[illegible]2	0 012

TABLE 3 *Level of protein bound stable iodine in the serum (PBI) before and after operation*

The values are expressed as the difference from the preoperative values

	Before operation	After operation (diff)				
		4 hr	1 day	3 days	6 days	12 days
n	16	5	16	16	14	8
x	5.92	+0.40	0.09	+0.29	0.66	0.79
S.E.		0.270	0.322	0.402	0.302	0.289

Exogenous thyroxine increases the excretion of cortical steroids (Corvilain 1953) and causes adrenal hypertrophy (Hoskins 1910, Wallach & Reinecke 1949).

The real mode of action in this "feed back" mechanism of the adreno-thyroidal system is still unknown. Cortisone does not interfere with the thyroid simply by changes in peripheral factors such as increased utilization of thyroxine or increased renal clearance of I^{131} (Perry & Gemmel 1949). It probably also acts directly on the thyroid cells and diminishes their ability for TSH at the target organ level but not by depressing TSH production or release from the pituitary (Perry 1951). This theory is supported by the fact that cortisone reduces the I^{131} uptake in TSH treated hypophysectomized rats (Epstein *et al.* 1953).

The metabolic changes after surgical stress are also complicated by extra-thyroidal factors such as protein loss, changes in electrolyte and liquid balances and the effect of adrenaline. The effect of the stress on the thyroid naturally varies according to the severity of the operational trauma and this may explain why results given in the literature vary.

In the present study a reduction in the thyroid uptake was noted for 18 hours after severe operation, i.e. the same period in which Gemzell (1955) observed a postoperative increase in 17-hydroxy-corticosteroids.

After slighter operations there is no significant drop in the uptake of I^{132} during the immediate postoperative period, but the increase in the uptake 24–48 hours after the operation may be a compensatory hyperactivity following a short period of stress during the first six postoperative hours (see Table 1).

The study also shows that radioiodide accumulation in the thyroid is more influenced by the severity of the surgical trauma than by the type of anesthesia. No difference was observed among patients with slighter operations, six of whom had been operated under local anesthesia and nine under general anesthesia.

The short period of increased hormone relase immediately after operation is followed by a period of reduced hormone release, which in severe opera-

tions may last as much as one week (Franksson *et al*, 1959) In the present study it lasted only 48 hours, but then only patients with lighter operations were examined

The PBI concentration was slightly raised four hours after operation and measurably depressed 6–12 days afterwards, though neither of these changes was significantly different from the preoperative values This is in accordance with earlier observations (Peters & Man, 1955) It is difficult, however, to assess changes in the concentration of PBI They are largely dependent upon extrathyroidal factors and postoperative changes in the liquid and electrolyte balances, and are not necessarily caused by postoperative changes in the function of the thyroid as the result of stress

ZUSAMMENFASSUNG

Der Einfluss des operativen Stresses bei Hals und Mundoperationen auf die Schilddrüsentatigkeit wurde mittels Messungen der Radiojodspeicherung in der Schilddruse, der Abgabe von Hormon (PBJ[131]) und des Serumspiegels von eiweiss gebundenem stabilen Jodid (PBJ) untersucht

Nach schwerem Operationsstress war die Radiojodspeicherung in der Schilddruse fur die Dauer von 48 Stunden gesenkt Nach kleineren Operationen in Lokalanasthesie oder auch Totalnarkose war sie wahrend der ersten 6 postoperativen Stunden unverandert, danach aber bis zum 7 postoperativen Tage erhöht, mit einem Maximum am 3 und 4 Tage

Die Serumkonzentration von PBJ[131] zeigte einen nahezu linearen Anstieg ohne signifikanten Unterschied zwischen operierten und Kontrollfallen In der operierten Gruppe war in den ersten 4 postoperativen Stunden doch ein leichter Anstieg der PBJ[131] Konzentration zu verzeichnen Sie stieg wahrend dieser Stunden um ⅓ des gesamten Tageswertes und um die Halfte des 48 Stunden Wertes Das deutet auf eine schnell einsetzende, postoperative, vermehrte Ausscheidung von Schilddrusenhormon hin, welche von einer 2tagigen Periode verminderter Hormonabgabe gefolgt war Dass kein signifikanter Unterschied zu den Kontrollfallen vorlag, mag darauf beruhen, dass in der untersuchten Patientengruppe keine schweren Operationsfalle vorhanden waren Zwischen Lokalanasthesie und Totalnarkose fand sich kein Unterschied

Die PBJ Konzentration von 16 operierten Patienten war 4 Stunden nach der Operation leicht erhoht und 6–12 Tage nach der Operation leicht gesenkt in beiden Fallen statistisch jedoch nicht signifikant Auch hier bestand kein Unterschied zwischen Lokalanasthesie und Totalnarkose

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TERMINATION OF THE OLIVO-COCHLEAR BUNDLE IN RELATION TO THE OUTER HAIR CELLS OF THE ORGAN OF CORTI IN GUINEA PIG

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A. Section of the olivo-cochlear bundle at the facial colliculi area in the guinea pig produced the following results:

1. Many large granulated nerve endings type 2 were found consistently degenerated. They are the ultimate terminals of the crossed olivo-cochlear bundle in efferent nature.

2. A considerable number of large granulated nerve endings were left intact on the outer hair cell. They may be the terminals of the homolateral fibers of the superior olivary complex or of some other origins.

3. The outer sensory cell showed some changes.

4. The tunnel spiral bundle carried some of the crossed efferent cochlear fibers.

5. Basal turn showed more degenerative large nerve endings than higher turns.

6. Small nerve endings remained normal or affected some degree secondarily to the disintegration of the adjacent large nerve endings.

B. Section of the auditory nerve at the internal auditory meatus demonstrated degeneration of small nerve endings and atrophic changes in spiral ganglia. The small nerve endings are afferent terminals.

INTRODUCTION

Rasmussen (1946, 1953) described the crossed efferent fibres of the olivo-cochlear bundle originating from the superior olivary complex and running in the direction of the organ of Corti in the osseous spiral lamina of the cochlea in the cat. Since that time the olivo-cochlear bundle has been investigated by various methods to determine its ultimate terminal. Neurophysiological investigations in these nerve tracts have been advanced at the same time (Galambos 1956, 1960; Desmedt & Monaco 1961; Fex 1959, 1962; Ruben & Sekula 1960). With silver stained materials Fernandez (1951) and Portmann & Portmann (1952) were able to follow the efferent

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tracts to the inner hair cell. Schuknecht, Churchill & Doran (1959) demonstrated that the section of the efferent bundle at the facial colliculi area reduced acetylcholinesterase activity in the organ of Corti in the cat. Acetylcholinesterase activity was also shown by Rossi (1961) in the intraganglionic spiral bundle, which is known to contain both efferent and afferent auditory nerve fibres.

Electron microscopic studies of the neurosensory area of the normal cochlea and vestibular apparatus revealed that these sensory cells have two or more different kinds of nerve endings in the guinea pig (Engström & Wersäll, 1953; Wersäll, 1956) and in the cat (Spoendlin, 1960). Large granulated nerve endings on the outer sensory cell of the cochlea were suggested to be efferent in nature (Engström & Wersäll, 1958; Engström, 1958; Smith & Sjöstrand, 1961). Recently Wersäll, Hilding & Lundquist (1961) have shown that the area of the large granulated nerve endings took more intense staining with Holmstedt's method for demonstration of acetylcholinesterase, whereas the small nerve endings, which have been suggested to be afferent, showed little or no staining.

All these findings have indicated that there is a double innervation on the organ of Corti; however, no definite evidence is yet available as to which terminal is afferent or efferent, and whether the large nerve endings are the efferent terminals of the olivo-cochlear bundle or of other origins.

Our present experiment was aimed specifically to find the ultimate terminals of the crossed olivo-cochlear bundle by cutting its tract at the facial colliculi area and examining the terminal nerve fibres and nerve endings at different stages postoperatively with the aid of the electron microscope. The auditory nerve trunk was also cut at the internal auditory meatus to provide further evidence.

MATERIALS AND METHODS

Guinea pigs were chosen for this experimental purpose, since the inner ear of this animal has been more thoroughly investigated with the electron microscope and also more analysed electrophysiologically than that of other animals. Seventeen guinea pigs weighing 250 to 350 g were operated under sterile conditions, fourteen for the section of the olivo-cochlear bundle and three for the auditory nerve trunk section.

Surgical approach to the olivo-cochlear bundle was as follows. A midline skin incision was made from the anterior margin of the occipital ridge to the back of the neck, and after severing the muscle attachment, the dorsal part of the occipital bone was removed with a fine rongeur starting from the foramen magnum toward the ridge anteriorly. The dura was incised open first above the apex of the medulla, and the cerebellum was gently lifted up with the tip of a fine forceps, which was wrapped with cotton in order to avoid an unnecessary trauma and at the same time to soak out cerebrospinal

fluid Section of nerve tracts was made at midline on twelve animals and at one side on two animals on the floor of the fourth ventricle with a fine knife extending beyond the facial colliculi area The distance from the obex to the anterior margin of the facial colliculi was marked on the knife After covering the exposed cerebellum with the dura a small piece of gelfoam was placed on the bony defect and the incision was closed

Surgical approach to the auditory nerve trunk was fairly similar to the above procedure except that the cerebellum and medulla were pushed medially with cotton on which a fine glass suction tip was placed with a very weak suction force The suction tip guided the cotton toward the internal auditory meatus passing below the paraflocculus which remained in its original place The auditory nerve was cut at the rim of the meatus sparing the superior vestibular nerve and the main vascular vessel No attempt was made to save the tracts of the olivo cochlear bundle

Animals operated for the study of the olivo cochlear bundle were sacrificed postoperatively at different time intervals in varying numbers one day one two days two three days three four days three five days two seven days two and one month one The animals for the auditory nerve trunk section were sacrificed at three four and seven days postoperatively checking cochlear blood flow just before sacrifice at the apex without the necessity of making any fenestrum The opposite cochleae of these animals of the eighth nerve section were used as a control for the entire series The inner ears were fixed in 1% buffered osmium tetroxide intravitally and within one to five minutes after the heart was cut off The round window oval window and apex of the cochlea were opened very quickly and the fixative was slowly pushed inside from a fine glass pipette In 70% alcohol the cochlea was separated from the vestibular portion which was saved for future purposes In order to facilitate dehydration and plastic penetration a small area of the otic capsule on the third second and basal turns was removed exposing the scala tympani and scala vestibuli The entire cochlea was embedded in Epon according to Luft (1961)

The embedded cochlea was bisected longitudinally with a rigid razor blade which was placed ventrally on the basal turn [illegible] mm from the basal end The cut surface remained shiny without distorting the general appearance of the cochlea Each half was bisected a few more times These tiny pieces were localized in the cochlear distance with an accuracy of 1 2 mm without venturing into actual measurement since the cochlear reconstruction from the serial sections of the celloidin method provided us the averaged spiral graph on which the cochlear distance was clearly marked The dissected specimens were orientated and fixed on Epon blanks with the Epon mixture saved at the time of the embedding procedure Three cutting angles were used the tangential approach starting from the third row of the outer hair cell toward the inner hair cell (this was the most appropriate to show as many as sixty hair cells on the basal turn on a single section compared to the radial angle) perpendicular to the basilar membrane in a spiral direction



Fig. 1. Light micrograph showing the surgical lesion (arrow) at midline in the floor of fourth ventricle in the region of the facial genu. Sudan black stain.

and the frontal angle and parallel to the basilar membrane. Twenty two cochleae were cut with a LKB Ultrotome at the basal and third turns, often supplemented with other turns, and photographed with the Siemens Elmiskop I with an initial magnification of from × 1000 to × 20 000.

Guinea pig brains were fixed in 10% buffered formalin and subsequently stained with H & E, Sudan black, and Kluver's method. The intraganglionic spiral bundle in the Rosenthal canal was examined with the light and electron microscopes.

FINDINGS

Animals operated for the olivo-cochlear bundle showed no spontaneous nystagmus postoperatively. Two guinea pigs demonstrated weak positional nystagmus only for one day. All retained good pinna reflex.

The examination of all brains operated for the section of the efferent nerve tracts revealed that lesions extended beyond the facial genu (Fig. 1). The cochlear and vestibular nuclei were not damaged surgically in any of these specimens. The incision made on a more lateral aspect did not reach deep enough to cut the homolateral efferent nerve fibres.

In Rosenthal's canal of the cochlea the intraganglionic spiral bundle was found degenerated consistently (Fig. 2). In the electron micrograph the myelin sheath of the spiral bundle was disrupted, collapsed, and fragmented, while

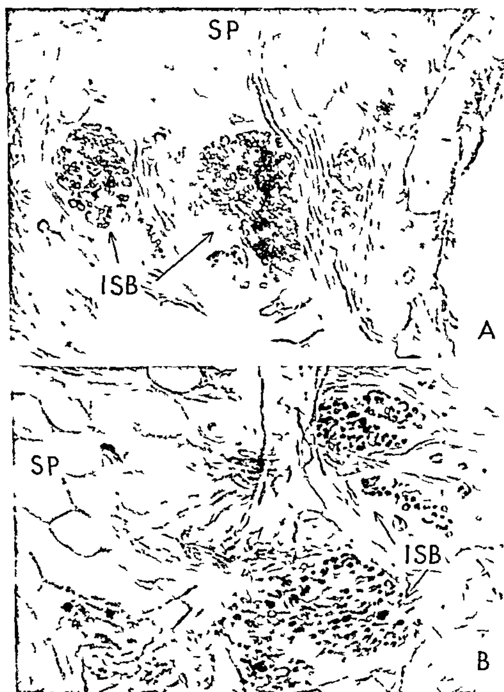


FIG [illegible] Photomicrograph of intraganglionic spiral bundles (*ISB*) and spiral ganglia (*SL*) from normal and operated animals. Free hand sections. (A) Normal in phase contrast. (B) [illegible] days postoperative. Basal turn [illegible] area.

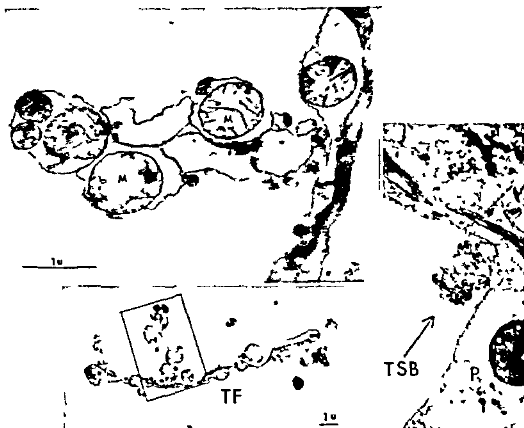


Fig. 3. Electron micrographs of the Corti tunnel showing tunnel spiral bundles (*TSB*), tunnel fibres (*TF*) and pillar cell (*P*) at basal turn 4 mm area, 3 days postoperative. The higher magnification of the tunnel fibres shows degenerative changes in mitochondria (*M*) and nerve fibres.

the axoplasm was often seen directly open to the protoplasm of the Schwann cell. There were no changes in the spiral ganglia and afferent nerve fibres.

In the Corti's tunnel, a varying number of tunnel spiral fibres and radially traversing tunnel nerve fibres toward outer hair cells were found undergoing a degenerative process. Mitochondria became extremely swollen with the disruption of cristae, and others appeared to change into dark osmiophilic masses. The axoplasm became less opaque, losing neurofibrilles, and eventually all contents were released free in fluid space with the breakdown of neurilemma. These atrophic nerve fibres in the tunnel spiral bundle travelled some distance with normal appearing nerve fibres (Figs. 3, 4).

All specimens with exception of the control (Figs. 5, 6) and the one- to two-day specimens definitely demonstrated the disintegration of large granulated nerve endings on the outer hair cell. The earliest changes were observed in the two-day postoperative specimens. Degeneration of the large nerve endings extended from base to apex with a tendency to affect more the lower turns. The number of atrophic nerve endings varied from one hair cell to the



Fig. 4 Electron micrographs showing tunnel spiral bundles and a part of pillar cell (P) from normal and operated animal. (A) Normal (B) 7 days postoperative. Note degenerating efferent nerve fibres (arrow). Basal turn area.

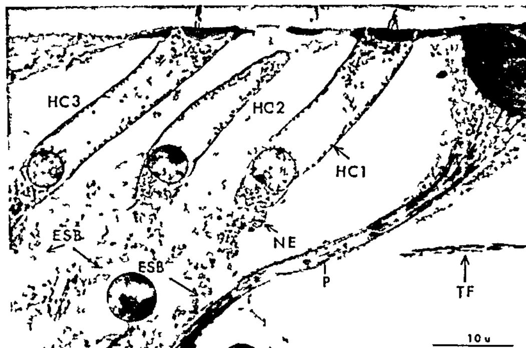
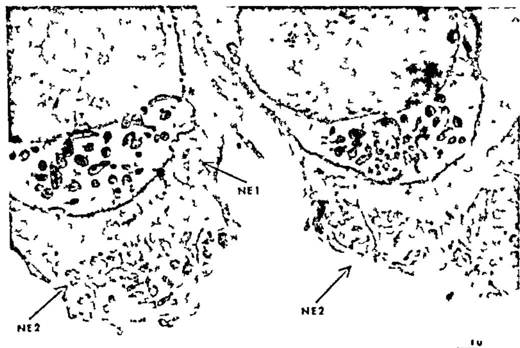


Fig. 5. Electron micrograph of normal organ of Corti showing hair cells first row (*HC*1) second row (*HC*2) third row (*HC*3) nerve endings (*NE*) tunnel fibres (*TF*) external spiral bundl[illegible] (*ESB*) and outer pillar (*P*). Upper basal turn 9 mm area.



[illegible] Two [illegible] outer hair cells from first row of basal turn [illegible] area cut tangentially from [illegible] direction of [illegible] hair cells. One hair cell shows all large nerve endings (*NE*2) and the other [illegible] small nerve endings (*NE*1) with large endings.

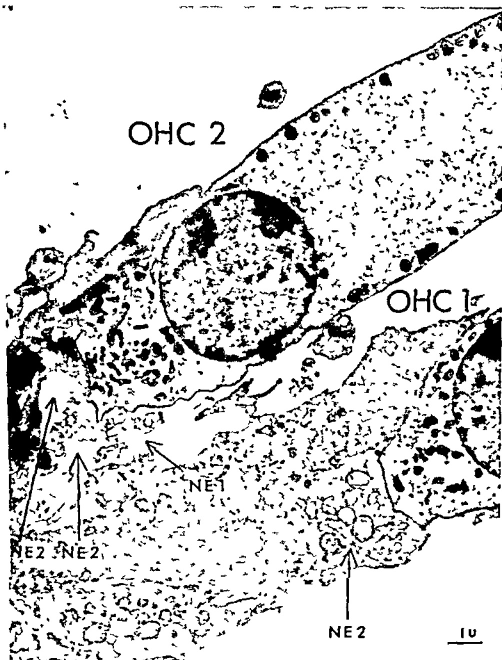


Fig. 7. Low magnification of outer hair cells from first (*HC* 1) and second (*HC* 2) rows of basal turn showing degenerative changes in large nerve endings (*NE2*). The small nerve ending (*NE1*) situated next to the degenerating large ending shows some changes. See text. Basal 7 mm area. 3 days postoperative.

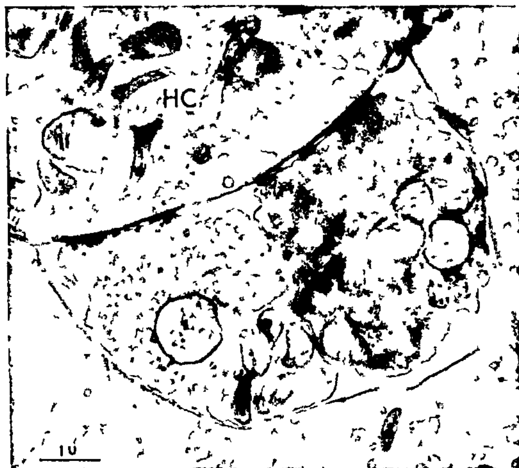


Fig 8 Electron micrograph showing two large nerve endings on the outer hair cell (HC) 4 days postoperatively from second turn 13 mm area The nerve ending on the right contains numerous small dark osmiophilic vesicles

next one in the same row and from one row to another Not all large nerve endings became degenerative and in fact quite a few large ones of normal appearance were located adjacent to the disintegrated terminals The most apparent transitional changes were observed in the specimens of the three to five day series (Figs 7 8 9) while in the specimens of a longer series it became increasingly difficult to determine whether the empty space below the sensory cell had formerly been occupied by nerve endings or whether it merely represented a normally existing space (Fig 12) The cochlea in which the olivocochlear bundle was cut laterally showed a similar degree of degeneration and the opposite cochlea demonstrated no definite disintegration except occasional swelling of mitochondria

Large granulated nerve endings were observed in various stages of degeneration In the early stage vesicles became patchy with the reduction or aggregation at ... and later while one nerve ending showed numerous ... compact vesicles (Fig 8) others showed a decrease in the



Fig. 9. Electron micrograph showing two degenerating (arrow) and two normal large nerve endings. Note disintegration of the plasma membrane in one of them. Stringy or filament like structures can be seen inside and along the cell wall of the outer hair cell. Third row, basal turn 5 mm area. 5 days postoperative.



Fig. 20. El tr n i crograph sl owing a late st ige of comp lete disintegr tion of large nerve en l ngs (rr s). Two outer h r cells fro thir l ro l asal t rn C n m area 1 lays postoj er itive

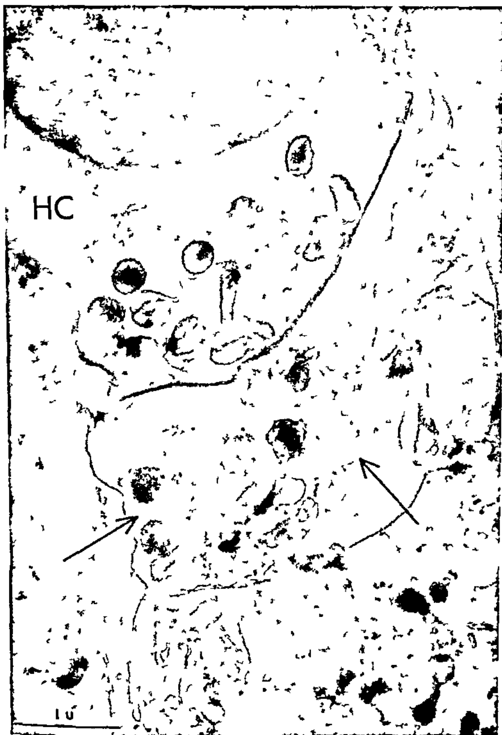
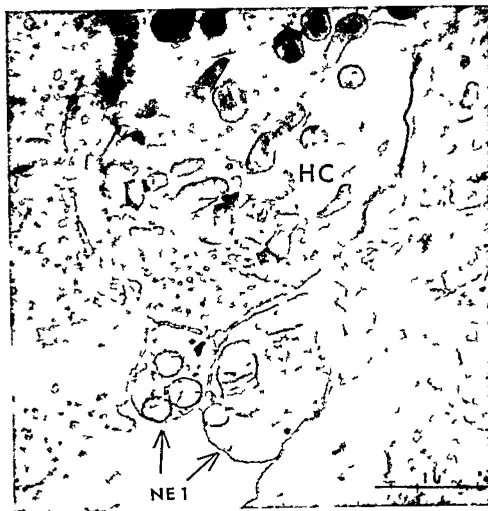


Fig. 11. Electron micrograph showing a late stage of degenerating large nerve endings (arrow). Mitochondria are seen in dark oval shaped masses with separating and degenerating outer membranes. Second row outer hair cell (*HC*), basal 4 mm area, 7 days postoperative.



Fig. 12. Electron micrograph of a late change in which the large nerve ending has disappeared between the small nerve ending (NE1) and large nerve ending (NE2). Presence of the broken accessory membrane inside the hair cell (HC) indicates that the large nerve ending was there. Note a wider space between two layers of the accessory membrane. First row, third turn 16 mm area, 7 days postoperative.



F o 13 Electron n crograph of a one month spec men show ng changes in the small nerve en l ngs (N E1) and outer ha r cell (*HC*) M tochondria in the nerve en l n s are swollen There is a wi ler gap between the ha r cell and one of the sma l nerve en l ngs Note the greater concentration an l increase in s ze of vesicles in the outer hair cell Secon l row l asal tu n mm area

number of vesicles with a consideral le variation in size and shaj e an l even increase in vacu olation (Figs 9 10 14c) Mit ch n lria were extremely swollen disrupting the normal arrangement cf cristae an l l ecame dark cval shaj ed masses on which the cuter meml ranes were sej arate l an l disintegrate l There was a ccnsistent definite disri pti n in the j lasma membrane of the large ending from the three day sj ecimens (Figs 7 9 10 11) At the neurosensory juncti n the distance l etween tl e surface cf the nerve en lings an l the bottom cf the sens ry cell varic l ccnsi leral ly fr m a wi le gap t n rmal The l r ken plasma meml rane cf the larg en lings stayed m re ften in the same normal j sit n even wl en all inclusi ns were released uts le (Figs 9 10)

The small nerve endings generally had a normal appearance. However, in some specimens we observed changes in vesicles, swelling of mitochondria even after one month (Figs. 7–13). Only in a few instances was a questionable degeneration seen in the immediately adjacent area of extensively affected large endings at the basal turn.

The outer sensory cell revealed a few changes. While mitochondria remained apparently normal throughout the entire series, except occasional changes in shape, there were often increases in concentration and size of vesicles, presence of more stringy or broken membranous structures scattered in the cytoplasm or laid against the accessory membrane, and vacuoles in the subnuclear portion (Figs. 9, 13, 14). At the hair bearing end, black granules or masses were observed a little more frequently than in the normal animals. The space within the accessory double membrane became wider, and the membrane itself somewhat detached from the hair cell, occasionally segmented or disintegrated (Figs. 12, 14).

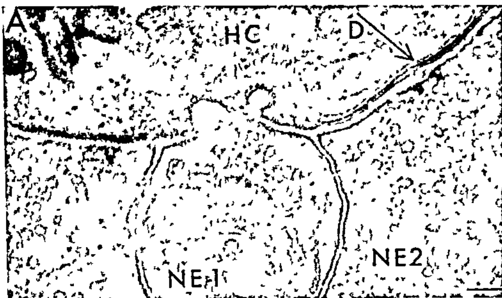
Animals in which the eighth nerve was sectioned showed little or no spontaneous nystagmus. They were not dizzy, and their superior vestibular nerve and blood circulation to the labyrinth, which was examined just before sacrifice, were not impaired. The pinna reflex was largely reduced throughout. Both large and small nerve endings were disintegrated more predominantly at the basal turn in the early stage. The small terminals often showed lesser and slower changes than the adjacent large nerve endings, in which the lesion was very extensive and appeared more quickly. The morphological changes within the small terminals were fairly similar to those of the olivo-cochlear nerve section (Fig. 15). In the modiolus, the spiral ganglia and intraganglionic spiral bundle were found in an atrophic state.

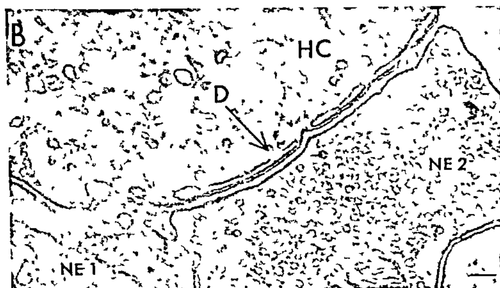
DISCUSSION

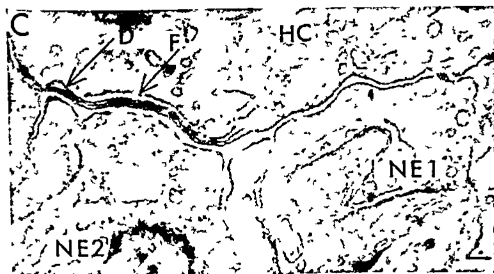
The experimental results of sectioning the efferent cochlear bundle have been reported in the cat by Rasmussen (1946, 1953), Schuknecht, Churchill & Doran (1959), and also in the caiman and pigeon by Boord (1961). Due to the limitation of methods and optics, the precise terminals of the cut nerve fibres could not be determined. According to the acetylcholinesterase study of Schuknecht *et al.*, the efferent terminals were located on or very close to the sensory cell in the organ of Corti.

From electron microscopic investigations of normal cochleae, two or more

Fig. 14. Electron micrographs of high magnification showing changes in outer hair cell (*HC*) and large nerve endings (*NE2*) in operated animals (B–E) in comparison to the normal (A). (B) It shows higher magnification of Fig. 12 with changes in accessory membrane and vesicles in the outer hair cell 7 days postoperative. (C) It shows increase in concentration and size of vesicles and appearance of stringy or membranous structure (E) on the accessory membrane (D). The large nerve ending (*NE2*) is atrophic. Basal turn, 5 mm area, 5 days postoperative. Note that the small nerve endings in the normal and operated animals lack the accessory membrane. Bars in the right hand corners represent 1000 Å.


A
HC
D
NE1
NE2


B
HC
D
NE 2
NE 1


C
D
F
HC
NE1
NE2

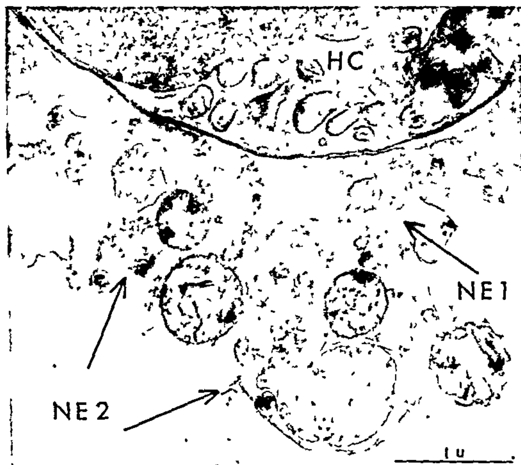


Fig. 15. Electron micrograph from a specimen in which auditory nerve trunk was cut at the internal auditory meatus, showing degeneration in both large (NE2) and small (NE1) nerve endings. Note lack of the accessory membrane in the outer hair cell (HC) in the adjacent area of the small nerve ending while it is clearly discernible in the area of the large ending. First row, basal turn area, 7 days postoperative.

different types of nerve endings were described on the outer hair cells: type 1, small nerve endings containing a smaller number of vesicles, and type 2, large nerve endings containing many vesicles (Engström 1958). Recently Smith (1961) described type 2A endings similar to type 2 but having more contact on other neural structures than the hair cell, and proposed that type 2A endings could be the terminals of the olivo-cochlear bundle. Engström (1961) in discussing Smith's presentation stated very briefly that the number of granulated nerve endings at the outer hair cell diminished after section of the efferent bundle in the fourth ventricle. Type 2 endings were proposed to be efferent in nature. Further evidence came from Wersäll, Hilding & Lundquist (1961) who demonstrated that acetylcholinesterase activity was more pronounced in the area of large nerve endings along the basilar membrane.

Our present investigation revealed that type 2 endings large nerve endings were consistently disintegrated Therefore we conclude that the final terminals of the crossed olivo cochlear bundle reach to the outer hair cell and that they are represented in type 2 endings The *possibility remains that type 2A* endings are also terminals of the olivo cochlear bundle since according to Smith s description they are very similar to the type 2 endings

There were however a considerable number of large nerve endings of normal or abnormal appearance left on the outer hair cells They might correspond to the terminals of the homolateral efferent cochlear bundle as described in the cat by Rasmussen (1960) or perhaps other terminals of unknown origin The abnormal nerve endings including both types in the vicinity of the disintegrated large terminals could be results of a secondary effect since they were in contact with each other possibly maintaining a close functional relationship

Electron microscopic investigations on nerve terminals of other denervated structures have been reported Robertis (1956) reported that most of the synaptic vesicles disappeared in 22 hours and that mitochondria degenerated in 44 hours in the ventral acoustic ganglia after destruction of guinea pig cochleae Reger (1959) in the investigation of the denervated neuromuscular junction reported a decrease in the number of vesicles an axonal terminal retraction, and degeneration of the terminals In our experiment we found the earliest changes in vesicles in two days and the most striking atrophies from three days with reduction in the number of vesicles extreme swelling of mitochondria and disruption of the plasma membrane of the nerve terminals However we occasionally observed large endings containing numerous small dark osmiophilic vesicles and swollen mitochondria the fate of these nerve endings was not clear The distance between the sensory cell and the de generating nerve endings varied to some extent but it tended to remain in the normal position more often Some of these changes were very similar to postmortal degeneration (Wersall Kimura & Lundquist)

Electrical stimulation of the olivo cochlear bundle has been reported to reduce action potentials at the round window (Galambos 1956 1960 Fex 1959 1962 Desmedt & Monaco 1961) augmentation of cochlear micro phonics (Fex 1959) and reduction of central auditory responses (Ruben & Sekula 1960) The effect of stimulation would be expected to be more pronounced at the basal turn and round window area since the large nerve endings were located more on the lower turns (Engstrom 1958 Smith & Sjostrand 1961) Prolonged electrical stimulation might produce histochemi cal changes in the efferent nerve endings of the cochlea De Robertis (1959) reported a reduction in the number and size of presynaptic vesicles in the nerve endings of adrenal medulla on electrical stimulation Others found no changes in the synaptic vesicles of the neuromuscular junction (De Harven & Coers 1959 Birks Huxley & Katz 1960) It has been suggested that the vesicles in the synaptic axoplasm may carry a chemical transmitter (De Robertis & Bennett 1955) and possibly represent packets of acetylcholine

(Robertson 1956). Recently Barrnett (1962) demonstrated acetylcholinesterase activity among other structures in the wall and in the content of vesicles at the myoneural junction. In our present experiment not only the efferent terminals were affected but also the adjacent structures to some extent. The sensory cell showed an increase in size of vesicles, appearance of stringy structures, vacuoles and disruption in the accessory membrane. The small nerve endings sometimes showed changes in mitochondria. All these changes could be the effects of substances which were unfavorable to them as the large endings were disintegrated. We could not, however, eliminate the possibility of direct inhibitory effect on the hair cell and small nerve endings and that these changes could be the effect of removing such inhibition.

Smith & Sjöstrand (1961) found synaptic bars in the sensory cells of the organ of Corti. The synaptic bars have been known to exist in the retinal rod synapse (Sjöstrand 1958). Their work and other normal morphological investigations indicated that the small nerve endings were afferent terminals of the eighth nerve. Our experiment on the cochlear nerve section demonstrated that the small nerve endings were degenerated and that there were atrophic changes in the spiral ganglia. The degenerative process in the small endings was much more delayed than in the large endings. This could be due to the fact that axones were cut, thus avoiding direct trauma to the spiral ganglia and dendrites. The spiral ganglia were apparently sustaining the life of small nerve endings somewhat longer, while in the efferent tracts the axones were detached peripherally from their neurones, causing them earlier atrophy. The large nerve endings in this group were almost completely degenerated in contrast to the section of the crossed olivo-cochlear bundle in which many large endings of normal appearance were left intact. It seems reasonable to conclude from these experiments that the large nerve endings are efferent and that the small nerve endings are afferent in nature.

ZUSAMMENFASSUNG

A. Sektion des olivo-cochlearen Bündels in der Gegend der Colliculi faciales beim Meerschweinchen führte zu folgenden Ergebnissen:

1. Viele grosse granulierte Nervenenden Typ 2 erwiesen sich durchwegs als beschädigt. Sie sind die letzten Enden des gekreuzten olivo-cochlearen Bündels efferenter Natur.

2. Eine anschauliche Anzahl grosser granulierter Nervenenden auf der äusseren Haarzelle waren nicht angegriffen. Möglicherweise sind es die Enden der homolateralen Fasern von der oberen Olive oder anderer Herkunft.

3. Die äusseren Sinneszellen zeigten einige Veränderungen.

4. Das Tunnel-Spiralbündel enthielt einige der gekreuzten efferenten cochlearen Fasern.

5. Die unterste Windung zeigte mehr beschädigte grosse Nervenenden als höhere Windungen.

6. Kleine Nervenenden verblieben unbeeinträchtigt oder trugen bis zu einem gewissen Grad sekundär zur Auflösung anliegender grosser Nervenenden bei.

B Sektion des Gehornervs am Meatus internus hatte Degeneration kleiner Nerven enden und atrophische Veranderungen in Spiralganglien zur Folge Die kleinen Nerven enden sind afferent

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STUDIES OF CRISTOSPINAL REFLEXES (LATEROTORSION)

I. A Method for Objective Recording of Cristospinal Reflexes

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An objective method for simultaneous electrical recording of the calorically induced cristo-ocular (nystagmus) and cristo-spinal (laterotorsion) reflexes is presented.

Pneumatic balloons inserted beneath both sides of the occiput of supine patients will record any movement of the head and neck as measurable pressure difference between the air cushions. After calibration the pressure difference can be expressed in grams and thus standardized.

The obtained recordings indicated an independence between these two reflexes despite a common stimulus. Since records adding information about laterotorsion to nystagmus may supply a further tool in the analysis of balance, detailed statistical studies of normal individuals and patients with known diagnoses will be presented in companion papers.

Clinical application of the principles of labyrinthine physiology demands simple, easily recorded measurements of different vestibular activities. Electronystagmography has provided a start and an impetus towards that goal. Other actions of the labyrinth than nystagmus must, however, be analyzed and methods devised for their measurement.

At least four main tracts connect the vestibular apparatus with different parts of the central nervous system. Thus, the maculae of the sacculi and the utriculi connect both to the motor optic pathways and to the cells of the ventral spinal horns and the cristae of the semicircular canals to motor optic and motor spinal centers.

In order to obtain as complete information as possible on the effect of vestibular stimuli the reactions of each of the four tracts should be objectively analyzed. In common clinical practice this has only been accomplished for the cristo-ocular reflex (nystagmus). In this paper a simple method for recording the cristo-spinal reflex will be presented.

This* investigation was supported by the Swedish Medical Research Council, by the Medical Faculty, University of Lund and also by a Special Fellowship BT 3 from the National Institute of Neurological Diseases and Blindness, Public Health Service, U.S.A.

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HISTORY

Studies of the vestibulo-spinal reflexes have contributed to a better understanding of the physiology of the vestibular apparatus. The goniometer test of von Stein (1904), the past pointing test of Bárány (1910), the arm deviation test of Bárány (1911), Guttich (1914) and Wodak & Fischer (1922), the walking, waltzing and stepping tests of Unterberger (1938), Hirsch (1940) and Fukuda (1959) may be mentioned in this connection. In 1923 Wodak & Fischer described all the turning, twisting and tilting movements of the entire body of patients exposed to labyrinthine stimulation. The body always moved in the direction of the slow component of the simultaneously provoked nystagmus.

In his study of the past pointing test, Bárány (1926) obtained a recording of the stretched index finger on a sheet of paper which in his opinion increased the accuracy of the test.

A direct graphical recording of the deviations of the movements of the arms was presented by Fischer & Wodak in 1924 simply by letting the patient hold a pencil in each hand pressed against a downward moving sheet of paper.

Three years later Talpis (1927) devised a photographic method. He eliminated the tactile influence by mounting electric lamps on the fingers and could thus record their movements. This method was refined by Nyman (1945), who used it for normals and patients exposed to producer gas. For details in the development of the various vestibulo-spinal tests the reader is referred to the monograph of Nyman (1945).

Behrman (1936) examined 631 normals using different tests. He concluded that past pointing practically always occurred in the predicted direction. Some few exceptions were considered to be accidental.

In 1960 a new method for the clinical recording of vestibulo-spinal reflexes was reported by Torok & Kahn, who recorded the rotatory falling tendency which they called lateropulsion.

An electromyographic clinical method applied in rotatory examination was described by Hara, Totsuka & Suzuki in 1960.

Nystagmus recording is rendered more difficult in the presence of the complicated body movements connected with the vestibulo-spinal tests because these movements cause electrical disturbances affecting the nystagmus record. The difficulty of using these tests is further complicated by the fact that they depend on assigned, controlled body movements and thus necessitate intercurrent cerebral activity. It has been shown that cerebral work (solving mathematical problems) is apt to change nystagmus patterns (Mahoney, Harlan & Bickford, 1957).

The lateropulsion test, the best present method for recording of the vestibulo-spinal reflexes, is performed with the patient in a sitting position. Any lateral sway in response to a rotatory stimulus is automatically counteracted by a compensatory movement of the body to prevent falling. Hence theoretically the deviation will be small as was also found by Torok.

Therefore the ideal goal should be the simultaneous recording of nystagmus and of the cristo spinal reflexes provoked by the same caloric stimulus. This can be achieved with the test person or patient placed in a relaxed supine position which gives him a larger base of support. Thereby many postural compensatory reflexes are excluded. Our method is based on such principles.

The lateral twist of the head, neck and body which follows labyrinthine stimuli occurs in the direction of the slow phase of nystagmus. We have called this twist laterotorsion in analogy with Torok & Kahn's (1960) lateropulsion in rotatory tests. We have preferred the term of torsion since we have noticed that the calorically induced movements have the characteristics of twist rather than of pull.

METHODS

The recording device was built up around an examining chair which can be placed in the standard positions used in eliciting caloric nystagmus. This chair has a sponge rubber padded device to support the patient's head in any given position.

Routine records were obtained of spontaneous, optokinetic, gaze and positional nystagmus and of calorically induced nystagmus according to the method of Henriksson (1955, 1956). Caloric stimulation was achieved by *irrigating with water of 30°C and 44°C in each ear during 40 seconds according* to the principles of Fitzgerald & Hallpike (1942).

To minimize fright and protective movements at the onset of the caloric test, catheters were introduced into the external canals of the ears and fixed by adhesive spray before the irrigations. The catheters were not removed until the examination was completed. The caloric test can thus be performed without any manipulations around the patient's head.

With the patient in a reclining position two cylindrical balloons (Fig. 1) were inserted between the head and the sponge rubber covered braces. Each balloon has three outlets, one for recording, one for adjusting and one for equalizing the pressure. Each recording outlet is connected to one of the two branches of a water manometer. The adjusting outlet allows the pumping of air into the system until a predetermined pressure is reached (30 mm of Hg). This pressure is adjusted after the head has been placed on the balloons in order to compensate for varying weights of the patients' heads. All tests were thus made at the same pressure level. The third outlet connects the two balloons to equalize the pressure between them before the test is undertaken but is closed during the examination. Thus any lateral twist of the head and neck will result in different weights on the two balloons causing unequal pressure within the two pneumatic systems.

Recording of the twisting movements may also be made electrically by means of two variable capacitors (Fig. 2)[1]. Changes in manometric pressure

[1] We gratefully acknowledge the help of engineer Ingvar Jonsson in designing the electric apparatus.

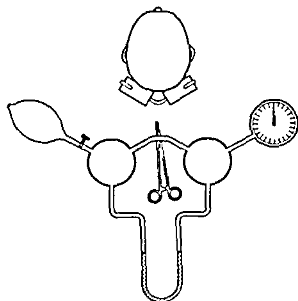


Fig. 1. A diagramatic drawing of the apparatus for recording laterotorsion.

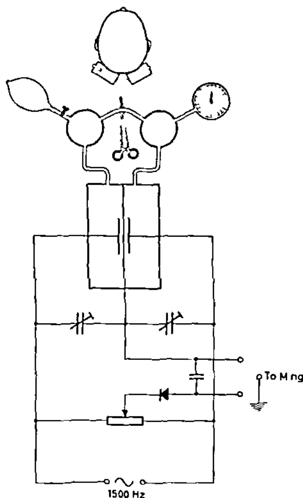


Fig. 2. A diagramatic representation of an electric capacitor device to record laterotorsion. The pressure gauge works as a differential condenser. The stainless steel diaphragm of the pressure gauge is 0.01 mm in thickness and has an area of 1250 mm².

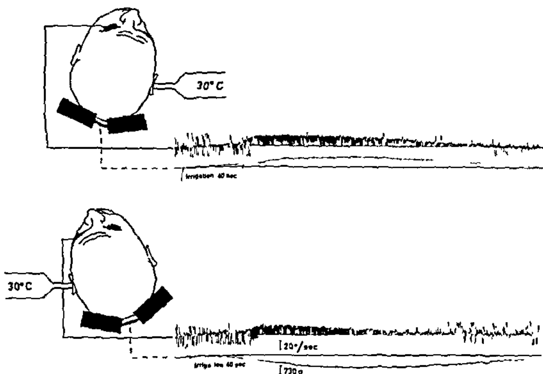


Fig 3 Sample record of simultaneously recorded nystagmus and laterotorsion Nystagmus is recorded above laterotorsion in each irrigation Laterotorsion towards the right is recorded upwards and towards the left downwards

in the two balloons shift the metal membrane which separates the two systems Since this membrane also functions as a common condenser plate for the capacitors the variation in manometric pressure will result in a change in the capacitances of the two condensers that can be electrically recorded Adjustment was made until a deflection of 1 mm on the Mingograph[1] corresponds to a difference of 1 cm between the water columns on the manometer On a Mingograph tracing the speed of the slow component of the caloric nystagmus is always recorded upwards while a laterotorsion to the right is recorded above and to the left below its base line (Fig 3)

Before using these two devices the relation between the manometric deviation in centimeters and the causative weight difference in grams was determined by calibration By expressing the laterotorsion in grams standardization between different apparatus would be established

The calibration was begun by placing 850 g in basic weights on each balloon This produced no relative change in the system but more closely approximated conditions of testing with the head on the balloons By then adding 100 g at a time to the basic weights and recording the deflection a calibration curve was obtained

[1] A two-channel recorder (AB Elema Stockholm)

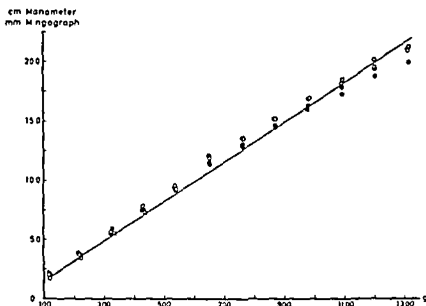


Fig. 4. Calibration curve for laterotorsion. Ordinate: O = manometer readings in cm. × = deflexion on Mingograph in mm. Abscissa: Difference in weight on the balloons in g.

Studies of such curves showed that the difference in pressure, obtained either from the Mingograph or from the manometer, is a linear function of the difference of the weights on the balloons (Fig. 4). Using our apparatus 1 cm on the manometer or 1 mm on the recording device was equal to 58 g pressure difference between the cushions. Thus, by multiplying the measured deflection by a factor of 58, weight differences exerted by the head and the neck in their lateral twist on the balloons can be determined.

When the balloons are introduced the test persons are instructed to keep their heads in the midline and their arms crossed on their chests. After they have become relaxed the connection between the balloons is closed with a clamp. Readings for spontaneous laterotorsion are recorded and/or read from the manometer after one and two minutes in both light and darkness. If there is instability or bizarre patterns the recording is repeated until stabilization is established.

Caloric examination is then performed using irrigation water of 30° and 44°C for forty seconds. The eye-movements are recorded on one lead of the Mingograph and pressure variations on the other. A sustained difference in weight on the balloons achieved either spontaneously or by vestibular stimulation will thus present a recorded measurement expressing the degree of laterotorsion.

An accurate and controlled physical stimulus of the vestibular organ and an exact method for recording the resulting eye movements has provided good information about the cristo-ocular reflex. Pressure difference recording adds the measurements of the simultaneously provoked cristo-spinal reflexes

to these records. Examinations of such curves demonstrate that these reflexes present different patterns. Laterotorsion can be seen on records in the absence of nystagmus and in other cases marked nystagmus can be found combined with minimum laterotorsion. Since this difference in the reflex response to a common stimulus has been shown to exist it may supply a valuable tool in further unravelling diagnostic balance problems.

Therefore two companion papers are being prepared. One presents a *statistical analysis of the results obtained from healthy volunteers. The other* a similar study shows the variations from the findings in normals in known cases of peripheral or central lesions affecting balance.

RÉSUMÉ

Une méthode objective d'enregistrement électrique des réflexes cristo oculaires (nystagmus) et cristo spinaux (latérotorsion) provoqués simultanément par une stimulus *calorique, est présentée* dans ce travail.

Des coussins pneumatiques mis entre les deux côtés de l'occiput de patients couchés dans les fauteuils d'examen enregistrent chaque mouvement de la tête et du cou sous forme de différences de pression mesurables entre les deux coussins.

Apres calibration de l'appareil la différence de pression peut etre exprimée en grammes et être ainsi standardisée.

Les enregistrements obtenus ont indiqué une indépendance entre ces deux reflexes en dépit du stimulus commun.

Les enregistrements qui ajoutent des informations sur la latérotorsion à celles sur le nystagmus peuvent fournir un nouveau moyen d'analyser l'équilibre des études statistiques détaillées faites sur les individus normaux et sur les patients à un diagnostic connu seront présentées par la suite.

ZUSAMMENFASSUNG

Eine objektive Methode elektrischer Registrierung von gleichzeitig calorisch induzierten cristo ocularen (Nystagmus) und cristo spinalen (Laterotorsion) Reflexen wird beschrieben.

Mit Luft gefullte Ballons werden zu beiden Seiten des Hinterkopfes der im Untersuchungsstuhl liegenden Patienten angebracht. Diese registrieren jede Bewegung des Kopfes und Nackens als messbare Druckdifferenzen zwischen den Luftkissen.

Nach Kalibrierung kann die Druckdifferenz in Gramm ausgedrückt und dadurch standardisiert werden.

Die erhaltenen Messungen deuten auf eine Unabhangigkeit zwischen diesen beiden Reflexen hin trotz eines gemeinsamen Stimulus. Registrierungsmethoden welche zusatzlich zum Nystagmus Information uber die Laterotorsion geben dürften ein weiteres Werkzeug fur die Analyse des Gleichgewichtes liefern. Deshalb werden detaillierte statistische Untersuchungen von Normalpersonen und Patienten mit analysiertem Krankheitsbild in folgenden Schriften mitgeteilt.

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DIRECTIONAL IMBALANCE OF VESTIBULAR NYSTAGMUS IN CAT FOLLOWING REPEATED UNIDIRECTIONAL ANGULAR ACCELERATION

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Cats were subjected to schedules of angular accelerations to determine if a marked nystagmic habituation to accelerations of one direction would "transfer" and thus cause a reduced nystagmus to accelerations of the opposite direction. All testing was in total darkness and animals were maintained in a state of continuous arousal with d-amphetamine. It was found that habituation does not transfer, that nystagmus in the untested direction remains undiminished, and that a directional imbalance is the result.

A reduction in ocular nystagmus occurs when an animal is repeatedly rotated. This response decrement, termed habituation, is a common finding for a wide variety of conditions and animals. The amount of acceleration experience and arousal or alertness have thus far been established as controlling variables. It is the purpose of this investigation to examine another characteristic of acceleration. In particular, will habituation to angular accelerations of one direction transfer to angular accelerations of the opposite direction?

As pointed out by Holsopple (1924), it is not appropriate to compare clockwise (CW) rotations against counter-clockwise (CCW) rotations if suprathreshold accelerations and decelerations are employed during rotations in both directions. It is a clear requirement that it is the accelerations which must be unidirectional, and that this necessitates a series of rotations in which, for example, suprathreshold accelerations are separated by subthreshold decelerations. A second requirement is that vision must be excluded to prevent the intrusion of an optokinetic nystagmus and its after-effects (Mowrer 1937) in the vestibular oculomotor responses. Previous "transfer" experiments (Dodge 1923, Holsopple 1924, Mowrer 1934) failed to meet both of these critical requirements.

A third requirement for a transfer experiment is defined by the recent data showing that the level of arousal or alertness is a powerful determiner of the nystagmic output in both cat (Crampton & Schwam 1961) and man (Collins 1962, Collins, Crampton & Posner 1961, Collins & Guedry 1962, Guedry & Lauver 1961), and that nearly any change in the environment will

alert a subject and thus produce more nystagmus. A test trial, a positive acceleration for example, following a long series of negative accelerations *may serve to arouse the animal and this arousal would contaminate the* results. Or, conversely, if the state of arousal is less on the last test trial than on the first, nystagmus would be reduced because of this extraneous factor. Obviously, an experiment designed to measure the directional influence of accelerations on habituation must provide for control of arousal.

The transfer of nystagmic habituation in the unanesthetized cat was evaluated with control of the known critical variables: (*a*) All animals were stimulated in total darkness to insure that only a vestibular nystagmus was elicited. (*b*) Arousal was maintained in the animals with d-amphetamine so that variations in arousal level would not produce variations in nystagmic output. This method of controlling arousal during vestibular experiments with the cat has been evaluated in detail (Crampton 1961). (*c*) An experimental design was employed in which suprathreshold accelerations were interposed between long periods of subthreshold decelerations. (*d*) A control group was used to evaluate collectively three suspected sources of error: variations in the corneo-retinal potential, habituation to the general testing situation, and variations in drug effects over the course of the experiment.

METHODS

Apparatus

The turntable provided controlled angular acceleration programs by means of electronic circuitry (Guedry & Kalter 1956). The animals were placed within a light-proof, electrically shielded metal enclosure. Needle electrodes inserted in skin at the outer canthi served to record the electronystagmogram (ENG) and a second pair inserted in skin on the crown served to monitor the electroencephalogram (EEG). All potentials were led from the turntable through slip rings and recorded on an Offner Type T electroencephalograph. The RC time constant for the eye movement amplifiers was 1.4 sec.

Procedure

Three groups of ten cats each were employed. At least two days prior to testing each cat was anesthetized with Nembutal and holes were drilled in its canine teeth for restraint purposes according to the technique of Henriksson, *Fernandez & Kohut (1961). On the day of testing each cat received an inter*peritoneal injection of 3 mg/kg body weight of d-amphetamine sulfate in saline solution and then was placed within the recording box with head mounted over the axis of rotation. The teeth were secured, the electrodes inserted, and the recording system tested for proper functioning. At 20 to 50 minutes following the injection, the animal was placed in complete darkness and the experiment begun. The EEG was monitored throughout the experiment to make certain that a fast, low voltage was always present

TABLE 1. *Testing schedule indicating direction of suprathreshold acceleration on each trial* [a]

Group	N	Preliminary period	Trials 1	2	3	4	5	6	7	8	last
A	5	CW	pos	neg	neg	neg	neg	neg	neg	neg	neg
	5	CCW	neg	pos	pos	pos	pos	pos	pos	pos	pos
B	5	CW	pos	neg	pos	pos	pos	pos	pos	pos	neg
	5	CCW	neg	pos	neg	neg	neg	neg	neg	neg	pos
C	5	CW	pos	neg	—	—	—	—	—	—	neg
	5	CCW	neg	pos	—	—	—	—	—	—	pos

[a] The *pos* and *neg* identifications refer to positive and negative angular accelerations according to a convention in analytical mechanics. A positive acceleration is one that increases clockwise angular velocity or decreases counter clockwise angular velocity. A negative acceleration is one that increases counter clockwise angular velocity or decreases clockwise angular velocity. These suprathreshold accelerations were separated by long duration subthreshold accelerations of the opposite sign.

The experimental testing schedules for all 30 animals are shown in Table 1. A preliminary period of rotation preceded trial 1 for all animals. The turntable was accelerated at a subthreshold rate of 0.28°/sec² to a value of 10 rpm and held at this velocity for 30 min and then returned at the same subthreshold rate to a base speed of 1 rpm. This preliminary period was inserted to stabilize the retinal adaptation level and further to permit a period of habituation to the entire surroundings except for suprathreshold accelerations. The direction of this preliminary period is shown in Table 1.

Following the return to the 1 rpm base speed, the trial series was begun. Trial 1 began at 60 to 90 min from the time of the d-amphetamine injection. A trial commenced in the indicated direction with a 4.5°/sec² acceleration of 14.9 sec duration followed by a 10 sec period of constant velocity. The turntable was then returned to the base speed of 1 rpm with a subthreshold acceleration of 0.28°/sec² and 4 min 3 sec duration, stopped and started in the opposite direction at 1 rpm with brief subthreshold accelerations. In this rather complicated experimental design, trial 1 was intended as a preliminary trial. An animal may struggle or the amplifier gain may be inappropriate for faithful recording on the first trial. These difficulties led to the present design in which all groups were identically treated for the first and second trials except for the counterbalancing as to the initial direction of acceleration.

Trial 2 promptly followed trial 1, and the program continued as indicated for all animals in groups A and B. Group A received accelerations in the same direction throughout the remainder of the experiment. Group B received accelerations in the opposite direction for trials 3 through 8. Group C was

TABLE 2 *Variance analysis for trials 1 and 2*

Source of variation	df	Mean square	F
Between directions (neg then pos versus pos then neg)	1	0.0	—
Between cats in same group	28	217.11	
Between trials 1 and 2	1	241.01	4.24*
Interaction trial × directions	*1*	*62.03*	*1.09*
Interaction cats × trials	28	56.83	

* 0.05 level of significance

identically treated through trial 2, then for a period of 40 min between trial 2 and the last trial the animals were rotated at a constant velocity of 1 rpm, a time equal to the period in which groups A and B received stimulation trials 3 through 8.

RESULTS

The slow phase nystagmic excursions for the entire period of the primary nystagmus were cumulated and converted into millivolts for each cat for each trial as described in an earlier paper (Crampton & Schwam, 1961). Secondary nystagmus was not scored.

The first test was performed to ascertain if there were differences in the nystagmic output that could be attributed to differences in the direction of rotation alone. For this analysis the data from all thirty animals on trials 1 and 2 were divided into two groups, the fifteen animals experiencing first a positive and then a negative acceleration and those fifteen animals experiencing first a negative and then a positive acceleration. An analysis of variance was performed for repeated measures on the same animals (Edwards, 1950). The difference between the two groups (positive then negative versus negative then positive) and the interaction between trials and direction were not significant (Table 2). The difference between trial 1 and trial 2 was found to be at the 0.05 level of significance. Since this statistical test confirmed that the direction of the rotation (CW or CCW) was not of concern, each of the A, B and C groups was considered to be a homogeneous group of ten animals and are so plotted in Fig. 1.

Each of the three groups produces a specific item of information. Group A indicates the decrement in response which occurs when stimulation is in one direction only. Group B shows the loss in output when accelerations of the opposite direction are interposed between the 2nd and last test trials. Group C is a necessary control group to indicate what the nystagmic loss may be when no accelerations are interposed between the 2nd and last test trials.

In Fig. 1 it is seen that the three group means differed on trial 2. For this reason, analysis of covariance (Edwards, 1950) was used to evaluate the

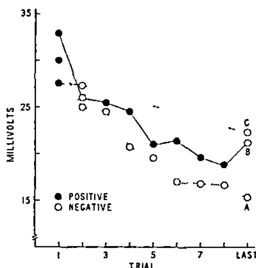


Fig 1 Average horizontal slow phase nystagmic output in millivolts for the entire period of primary nystagmus on each trial A trial consisted of a 4 5°/sec² acceleration of 14 9 sec duration followed by a long period of subthreshold acceleration of the opposite sign Each point indicates the average of 10 animals For clarity of exposition each group is represented as having the same schedule of accelerations although in fact the direction of acceleration was counterbalanced within each group (see Table 1)

differences between the three groups insofar as the output on the last trial was concerned This statistical method takes into account the differences due to sampling errors between the groups on trial 2 in the assessment of the differences between the groups on the last trial In Table 3 are the results of this analysis First, the differences between the groups with all three groups considered simultaneously was significant at the 0 01 level Considering the various pairings of the groups group A differed from group B and group C at the 0 05 and the 0 01 level respectively There was no significant difference

Table 3 *Covariance analysis for the data from trial 2 and the last trial*

Source of variation	df	Mean square	F
Adjusted means groups A B C	2	96 88	[illegible]**
Within groups	26	17 12	
Adjusted means groups A B	1	141 78	7 71*
Within groups	17	[illegible]	
Adjusted means groups A C	1	[illegible]	8 1 **
Within groups	17	18 93	
Adjusted means groups B C	1	[illegible]	
Within groups	17	12 02	

* 0 05 level of significance ** [illegible] level of significance

Table 2. Variance analysis for trials 1 and 2

Source of variation	df	Mean square	F
Between directions (neg then pos versus pos then neg)	1	0.0	—
Between cats in same group	28	2714	
Between trials 1 and 2	1	2411.03	4.29*
Interaction: trials × directions	1	612.03	1.09
Interaction: cats × trials	28	561.83	

* 0.05 level of significance.

identically treated through trial 2, then for a period of 40 min between trial 2 and the last trial the animals were rotated at a constant velocity of 1 rpm, a time equal to the period in which groups A and B received stimulation trials 3 through 8.

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In Fig. 1 it is seen that the three group means differed on trial 2. For this reason analysis of covariance (Edwards 1950) was used to evaluate the

a substantial amount of accelerative experience prior to his first testing, and his initial habituation has already been established It is known that special experience, in particular that associated with certain occupations such as piloting high performance aircraft (Aschan, 1954) figure skating (McCabe, 1960), dancing (Barany, 1907) or repeated exposure to conditions which produce the Coriolis phenomena (Guedry & Graybiel, 1962) is required to produce a further reduction in nystagmic output This additional violent and unique vestibular exposure may be identified as the critical variable for *producing further habituation in adult men* Whether visual stimulation must also accompany the vestibular stimuli needs further examination, since the evidence at hand is conflicting (e g, Mowrer, 1934 Wendt 1951) Nevertheless, it is known that a directional imbalance as a result of habituation of the nystagmic reaction can be produced in man as in the cat, without an apparent pathology, but certain occupational experiences are required Appropriately, this directional aspect appears to be related to the frequency of certain preferred directions in maneuvers (Aschan 1954 Barany, 1907)

ZUSAMMENFASSUNG

Versuchsreihen wurden durchgefuhrt, in denen Katzen Beschleunigungen nach verschiedenen Richtungen unterworfen wurden Es sollte hierbei festgestellt werden ob eine betrachtliche Nystagmus Gewohnung an Beschleunigungen in einer bestimmten Richtung , ubertragbar sei und so einen verminderten Nystagmus bei Beschleunigungen in der entgegengesetzten Richtung zur Folge habe Alle Versuche wurden in volliger Dunkelheit ausgefuhrt, und die Tiere wurden mit d Amphetamin dauernd wachgehalten Man fand dass Gewohnung nicht ubertragbar ist dass der Nystagmus in der nicht getesteten Richtung unvermindert bleibt und dass die Versuche eine Unausgeglichenheit des Nystagmus hinsichtlich der Richtung der Beschleunigung zur Folge haben

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LONG TERM RESULTS OF STAPES MOBILIZATION

A statistical analysis

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A new statistical procedure is presented by means of which the long term results of mobilisation surgery have been accurately predicted. This procedure takes into account the dynamical aspect of the otosclerotic disease, be it operated upon or not, which is largely responsible for the unreliability of the statistical data based upon the traditional methods of evaluation. It is demonstrated that transcrural or footplate stapes mobilisation is an unjustified operation in the early and rapidly progressing stages of otosclerosis, though it retains a certain validity in the slowly progressing disease of mature age, especially if the cases are carefully selected. The statistical method applied appears to be recommendable also in the prediction of the late results of the more advanced technics of stapes surgery.

INTRODUCTION

Only long term results allow a definite judgment upon the validity of any new surgical method. As far as transcrural or direct mobilization is concerned, available reports of long term results are scanty, however the general impression is far from being unfavourable.

For periods ranging from 2–5 years after the operation the average figure of lasting improvements is about 60%, even though extreme values such as the 80% of Rosen and Shambaugh and the 35% of Tato should be taken into account.

More recent reports show much less optimistic results. Guillon reports 28% after 2–4 years, 21% after 6 years; Bellucci 12% after 5 years for transcrural mobilization and 40% at 18 months for direct footplate mobilization. As a matter of fact most of the suroptimistic material produced is improperly collected or poorly elaborated.

Moreover the criterion used for classifying the so called "lasting results" is different from case to case: in some instances progressively deteriorating hearing levels are still considered "successes" provided the post operative gain is partially retained within certain arbitrary limits. Therefore for more than one reason we must look cautiously at these statistical reports.

Another fact deserves to be stressed: technical procedures have frequently changed in the last few years and very often in the hands of the same otosurgeons mobilization over the neck has given way to fenestration of the footplate or to direct manipulations over the footplate and crura or eventually to stapedectomy with interposition.

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One could scarcely justify what appears to be much more than a natural evolution of the stapes surgery, if the lasting results of classical mobilization were as good as is generally reported, that is, 60% or more, a figure which is not lower, even if not greater, than the percentage of successes obtainable by any functional operation on the middle ear.

That is the reason why, before drastically changing over to newer techniques, we tried our best to assess clearly which value, if any, may be attributed to classical extralabyrinthine mobilization over the neck or footplate in otosclerotic surgery, and possibly which elements, if any, contribute to make this surgical procedure acceptable or not.

Our first step has been that of periodically rechecking, for at least two years, all cases (206 out of 214) operated by the same surgeon with the same technique of extralabyrinthine stapes mobilization, having attained immediately after the operation the best possible anatomical and auditory results. However, we were not concerned with establishing how many patients had totally, subtotally or partially retained the post-operative gain two years after the operation.

Such a criterion is a static one and concerns the state of hearing at a certain time after the operation, which is always much too near to it and does not allow a foreknowledge of future modifications, considering the typically slow evolution of the otosclerotic process, with or without surgical interference. What we need is a dynamic evaluation of the post-operative hearing conditions, the only one suitable for a dynamic process such as otosclerosis, whether it is operated upon or not. Therefore, following the advice of a highly qualified statistician, Prof. Brambilla, we made resort to the stochrastic process as the only possible way of disentangling the complicated and so far unsolved puzzle of the recent results of mobilization. We think that a definite word on this long debated question may offer many other surgeons a proper criterion of evaluation.

General principles of the stochastic process theory

From a very general point of view we can say that a statistical variable is the expression of the variability of a system S characterized by states $S_0, S_1, \ldots, S_n$ (with n finite or infinite), which are the quantitative values of a variable through which we studied the above system. For instance, if we consider the statistical variable X describing the classification of N income receivers according to income X, states S_i are the different incomes or income classes and system S is the economic system (Italian, French, etc.) to which the observed experience refers.

If we classify N industrial products according to a given characteristic X (thickness, diameter, resistance, etc.), states S_i are the different intensities or intensity classes of X and system S is the productive process concerning our data.

If we consider as a variable X the number of work accidents which occurred in a given time interval in N similar firms or in N work shops, states S_i are the total number of accidents and system S is the technical economic organization of the production process.

By classifying N individuals according to their professions, we get the expression

of a socio economic system considered from the point of view of the "profession" which is regarded as a chance offered by the above system to an individual of utilizing his own capacities in order to transform them into individual income

All these examples point out the fact that the variability of a statistical variable is the expression of the several different situations or states which a system of forces (economic, social, biological, physical, etc) can present, while remaining at the same time the logical dimension of a unit system

Therefore, since now variable X will be written in the following form

$$[X_1, X_2, \ldots, X_n],$$

where X_i indicates the total number of cases concerning state S_i arbitrarily chosen (for values X_i or intervals) This being stated, if we wish to study the dynamics of a variable X we need to introduce the concept of transition from one situation to another At first by intuition we give to the term the meaning of a chronological time passing between two different situations, $X^{(1)}$ and $X^{(2)}$, denoting the evolution of a system S from moment t_1 to moment t_2 But if we want to give a real conceptual strength to the theory we are going to propound, it is necessary to give a physical dimension to the notion of transition

Since we cannot dwell long upon the subject, we appeal to the reader's intuition in order to make clear the deep general meaning of transition, and state that the term can take the following different meanings

(*a*) *generation*, in the field of demography and evolution of biological population
(*b*) *production or consumption period* in the field of economics
(*c*) *processing cycle* in the field of any productive technique (that is, in the widest sense)
(*d*) *a random test* carried out by set of boxes

These expressions do not exhaust all the possible interpretations which can be given to the transition concept However, they are the most important and common, in any case, they are sufficient to explain that the concept is an element suitable to describe the evolution in time of a system, and therefore can be ordered in the chronological time through expression of space, that is, of a more general system of forces where the system under consideration is moving

Now, in a transition each element of the system which was in the initial state S_i can, from a very general point of view, migrate to state S_j for all the i s and j's If this migration is left to chance, we can associate with it a probability p_{ij} that this will occur Therefore, if we want to give a general picture of all the migration possibilities in a transition period we can draw the following table

	S_0	S_1	S_2	S_j	S_n
S_0	p_{00}	p_{01}	p_{02}	p_{0j}	p_{0n}
S_1	p_{10}	p_{11}	p_{12}	p_{1j}	
S_2	p_{20}	p_{21}	p_{22}		
S_i	p_{i0}	p_{i1}	p_{i2}		
S_n	p_{n0}	p_{n1}	p_{n2}		

where, conventionally, rows denote the starting states and columns the final states of the transition, and quantities p_{ij} the probability that the system, which formerly was in state S_i will migrate to state S_j

The whole of probabilities alone is called *transition vector P* which is always $=1$ since it has the mathematical structure of a matrix which is of a particular type, as we can immediately see, since

(1) *the sum of all the probabilities by row is always* $=1$ (in fact, from any arbitrary initial state the system has to migrate to one of the possible states and therefore the sum of probabilities of all possibilities must be $=1$ owing to the principle that total probabilities $=1$), that is

$$\sum_{j=1}^{n} p_{ij} = 1 \quad (i, j = 1, 2, \ldots, n),$$

(2) *the number of rows and columns, that is of states* S_{ij} *can increase infinitely,*
(3) *all the numbers contained in these matrices are positive or zero as they are probabilities,* that is $p_{ij} \geq 0$

Denoting by P_1 the transition matrix and applying it to vector $X^{(0)} = [X_1 X_2 \ldots X_n]$ we get the final situation of the system after a transition in the form of a new variable $X^{(1)}$, where index (1) denotes the evolution of initial $X^{(0)}$ after the occurrence of all the possible migrations from a state to another. Therefore we have

$$[X_1^{(0)} \; X_2^{(0)} \; \ldots \; X_n^{(0)}] \begin{bmatrix} p_{11}^1 & p_{12}^1 & \ldots & p_{1n}^1 \\ p_{n1}^1 & p_{n2}^1 & \ldots & p_{nn}^{(1)} \end{bmatrix} = [X_1^{(1)} \; X_2^{(1)} \; \ldots \; X_n^{(1)}]$$

where

$$X_m^{(1)} = X_1^{(0)} \; p_{1i} + X_2^{(0)} \; p_{2i} + \ldots \; X_n^{(0)} \; p_{ni}$$

Then, if at the moment t_1 a new transition occurs in a given chronological time and leads us to consider the system at the moment t_2 we need to consider a new transition matrix P_2 which … is the former one, expresses the range of probabilities p_{ij}^2 associated with the several migrations in the second transition (whence the index (2) attached to the new p_{ij} s)

The product

$$[X_1^{1} \; X_2^{1} \; \ldots \; X_n^{1}] \begin{bmatrix} p_{11}^2 & p_{12}^2 & \ldots & p_{1n}^2 \\ p_{n1}^2 & p_{n2}^2 & \ldots & p_{nn}^2 \end{bmatrix} = [X_1^{2} \; X_2^{2} \; \ldots \; X_n^{2}]$$

shows the evolution of variable $X^{(1)}$ into $X^{(2)}$. Of course, the process can go on indefinitely. In compact form, after n transitions, we have

$$X^n = \{[X^0 \; P_1] \; P \ldots\} \; P_n$$

Definition and description of sampling methods

The foregoing introduction has been necessary in order to make clear the method by which the auditory results of stapes mobilization were elaborated as a function of the time elapsed since the operation

The population of otosclerotic patients may be considered as a system in which migrations may occur as a consequence of surgical interference. The aim of the present study has been to ascertain whether the post operative

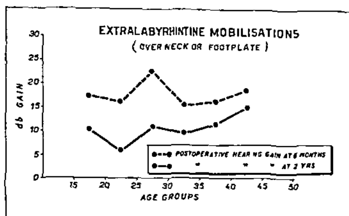


Fig 1

migration from one auditory state to another in the transition period considered tends to remain permanent or if it does not what are the mathematical rules governing the successive migrations and what is eventually the new and ultimate equilibrium which is expected to be reached by the system after a number of transitions

Of course the mobilized population of otosclerotics should be not only carefully collected but numerically significant and always the same at each successive test Likewise the accident which determines variations viz migrations in the system must be of the same kind in all cases which means that the operative technique employed must always be the same possibly the surgeon should also be the same Otherwise we should be compelled to introduce other factors of variability If these conditions are respected as they were in our study the method of investigation proposed appears to be most adequate to allow us to draw some definite conclusions regarding the validity of the surgical method concerned

In processing statistical data our population of patients was subdivided into two large age groups one including 108 subjects under 30 years of age and the other including 96 subjects over 30 years of age Such a large subdivision was made necessary in order to avoid or at least to reduce the possible errors of sampling that is to keep sampling variability within the limits of a natural variability

The age of 30 years was chosen as a limit between the two groups of the young and of the aged patients since in the statistical results of a former paper it was noted that it marked a sharp limit between quick and slow regression of the post operative gain (Figs 1–2)

Each age group was then further classified according to four states to use the terminology of the stochrastic process theory By state S_0 we denote a hearing loss of 0 30 db (practically the zone of social adequacy) by state S_1 a hearing loss of 31 40 db by state S_2 a loss of 41 50 db and by S_3 a loss of 51–60 db Thus at the beginning of the stochrastic process namely in the pre operative state the situation of our patients was as follows

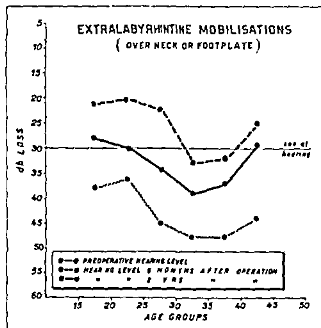


Fig 2

	Below 30 years	Above 30 years
State S_0 (0–30 db)	0 (0%)	0 (0%)
State S_1 (31–40 db)	54 (49%)	22 (29%)
State S_2 (41–50 db)	40 (36%)	24 (32%)
State S_3 (51–60 db)	14 (15%)	30 (39%)

This situation is mathematically defined by the matrix vector which will be (0–54–40–14) for subjects under 30 years and (0–22–24–30) for subjects over 30 years From now on the surgical operation is going to transform our system

At the first transition, that is, at an immediate post operative test, the structure of our system has undergone a complete transformation, since the distribution in the different states of the subjects belonging to the system is changed

In section 2 we observed that, generally speaking, any individual belonging to a system can pass from a state S_1 to any of the other states in our example a subject who, owing to a hearing loss of 31–40 db was classified in state S_1, can improve and migrate to state S_0 as well as get worse and migrate to states S_2 and S_3 or remain unchanged (remaining therefore in S_1) after the operation All this occurs with probabilities which are characteristic of the nature of the phenomenon under consideration

The situation of these migration probabilities from one state to another is expressed as percentages by transition matrices (Figs 3–4) The first transition matrix expresses the probabilities of migration to the different hearing states immediately after the mobilization operation and is compiled from the data directly collected and statistically worked out from audiometric tests 10 days

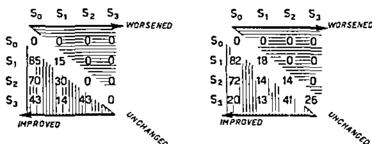


Fig 3

after the operation (Fig 3) The second transition matrix shows also as per centages the probabilities of migration to the different hearing states after the subsequent hearing tests (Fig 4)

This matrix is the arithmetic mean of matrices worked out from the direct tests at six months one year and two years respectively after the operation The adoption of the arithmetic mean is justified since it was observed that the matrices showed no significant percentual variations from one test to the next This means that the post operative hearing regression is continuous and constant and shows no variations in its dynamics as far as the slowing down or quickening of the regression itself is concerned Such an observation has induced us to use the above transition matrix also in transi tions more than two years after the operation

Let us first consider the age group under 30 years If we apply the matrix vector (0 54 40 14) to the first transition matrix we get

$$[0 \quad 54 \quad 40 \quad 14] \begin{bmatrix} 0 & 0 & 0 & 0 \\ 85 & 15 & 0 & 0 \\ 0 & 30 & 0 & 0 \\ 43 & 14 & 43 & 0 \end{bmatrix} = 68 \quad 24 \quad 12 \quad 4$$

At the first transition that is at the first test 10 days after the operation the situation is as follows 68 patients (63 %) have migrated to state S_0 and are to be considered successes 24 subjects (22 %) remain in state S_1

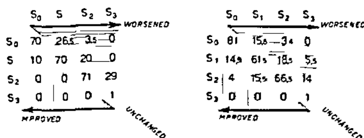


Fig 4

partly because they are in the same pre operative condition partly because they come from states S_2 or S_3 12 patients (11 %) make up state S_2 and four patients (4 %) make up state S_3 The same considerations made for state S_1 hold for these states too

Then if we analyse each row and column of our transition matrix we see that among the individuals belonging to state S_1 85 % reached social adequacy (the social hearing level) 15 % remained unchanged while no subject got worse In state S_2 70 % of the subjects have reached the social hearing level while the remaining 30 % have improved their pre operative condition and migrated to state S_1 In state S_3 only 13 % recovered completely while the remainder belonging to groups S_1 and S_2 improved their pre operative conditions only partially

If we now consider the general results we immediately observe that the more significant early results occurred in states S_1 and S_2 that is among the subjects with a pre operative hearing loss of less than 50 db

After the transformation of the system due to the operation the distribution of the subjects according to the different hearing states tends to change further in the following transitions

We now apply the second transition matrix to the matrix vector and get

$$[58 \quad 24 \quad 12 \quad 4] \begin{bmatrix} 0 & 26 & 3\ 5 & 0 \\ 10 & 70 & 20 & 0 \\ 0 & 0 & 71 & 9 \\ 0 & 0 & 0 & 10 \end{bmatrix} = [50 \quad 34 \quad 16 \quad 8]$$

At the second transition subjects remaining in state S_0 have diminished to 50 while those in state S_1 have increased to 34 and patients in states S_2 and S_3 to 16 and 18 respectively As a whole the distribution of our subjects tends to shift towards the groups with a greater hearing loss (states S_1 S_2 S_3) with a probability which is revealed by the transition matrix

At the second transition (after six months) an individual with a hearing level of 0 30 db (state S_0) has a 70 % probability of remaining in the same state 26 5 % of going back to state S_1 (31 40 db) a 3 5 % of migrating to state S_2 (41 50 db) and 0 % of passing to state S_3 (above 50 db)

Similarly a subject in state S_1 (hearing level of 31 40 db) has a 10 % probability of improving further and passing to state S_0 70 % of remaining in state S_1 20 % of passing to state S_2 and 0 % of migrating to state S_3 Subjects in states S_2 and S_3 have a zero probability of getting better

Continuing our mathematical computations we get

$$[50 \quad 34 \quad 16 \quad 8] \begin{bmatrix} 0 & 26\ 5 & 3\ 5 & 0 \\ 10 & 70 & 20 & 0 \\ 0 & 0 & 71 & 29 \\ 0 & 0 & 0 & 1 \end{bmatrix} = [38 \quad 38 \quad 20 \quad 12] \quad \text{3rd transition}$$

$$[38 \quad 38 \quad 20 \quad 12] \begin{bmatrix} 70 & 26\ 5 & 3\ 5 & 0 \\ 10 & 70 & 20 & 0 \\ 0 & 0 & 71 & 29 \\ 0 & 0 & 0 & 1 \end{bmatrix} = [30 \quad 36 \quad 21 \quad 18] \quad \text{4th transition}$$

$$[30\ \ 36\ \ 24\ \ 18] \begin{bmatrix} 0 & 26.5 & 3.5 & 0 \\ 10 & 70 & 20 & 0 \\ 0 & 0 & 1 & 29 \\ 0 & 0 & 0 & 1 \end{bmatrix} = [24\ \ 34\ \ 26\ \ 24] \quad \text{5th transition}$$

$$[24\ \ 34\ \ 26\ \ 24] \begin{bmatrix} 0 & 26.5 & 3.5 & 0 \\ 10 & 0 & 20 & 0 \\ 0 & 0 & 1 & 29 \\ 0 & 0 & 0 & 1 \end{bmatrix} = [20\ \ 34\ \ 26\ \ 28] \quad \text{6th transition}$$

$$[20\ \ 34\ \ 26\ \ 28] \begin{bmatrix} 0 & 26.5 & 3.5 & 0 \\ 10 & 0 & 20 & 0 \\ 0 & 0 & 1 & 29 \\ 0 & 0 & 0 & 1 \end{bmatrix} = [19\ \ 34\ \ 26\ \ 29] \quad \text{7th transition}$$

After the seventh transition the distribution of our population of patients remains unaltered though migrations occur under the same law. Therefore a *limit* state has been reached which represents a new equilibrium of the system. This last distribution represents the final auditory state reached by patients.

At the seventh transition, that is five years after the operation, only 19 subjects, the 18 % among all operated patients under 30 years, retain a hearing level within the limits of social adequacy. Subjects in state S_3 who at the beginning were 14 (13 %) increase to 28 (26 %) at the expense of *individuals belonging to other states. Such a remark leads to several assump*tions about the possible causes of this phenomenon.

Fig. 5 represents schematically the percentual consistency of each auditory state at each subsequent transition. The dotted vertical curve shows (see circles) the behaviour of the average hearing level from before the operation until five years afterwards. It is only indicative of the overall trend of the phenomenon.

Let us now consider the group of subjects above 30 years. If we apply the matrix vector (0 22 24–30) to the corresponding first transition matrix (see page 55) we get

$$[0\ \ 22\ \ 24\ \ 30] \begin{bmatrix} 0 & 0 & 0 & 0 \\ 82 & 18 & 0 & 0 \\ 72 & 14 & 14 & 0 \\ 20 & 13 & 41 & 26 \end{bmatrix} = [40\ \ 12\ \ 16\ \ 8]$$

Therefore 10 days after the operation the following situation occurs: 40 patients (52 %) have migrated to state S_0, that is have become successes; 12 patients (16 %) are in state S_1 (hearing level 31–40 db), 16 patients (21 %) are in state S_2 (hearing level 41–50 db) and eight patients (11 %) are in state S_3.

It should be noted, as far as states S_1, S_2 and S_3 are concerned, that the total number of subjects is composed partly of those remaining functionally unchanged and partly of those migrating from one state to another. Such migration probabilities are shown by the transition matrix, that is, subjects belonging to state S_1 have a 72 % probability of social recuperation and those in

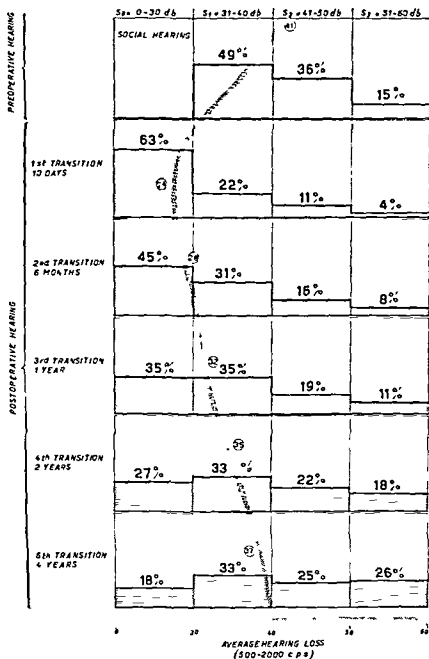

PATIENTS OF LESS THAN 30 YRS OF AGE - CASES n 108
S₀ = 0-30 db
S₁ = 31-40 db
S₂ = 41-50 db
S₃ = 51-60 db
SOCIAL HEARING
PREOPERATIVE HEARING
49%
36%
15%
POSTOPERATIVE HEARING
1st TRANSITION 10 DAYS
63%
22%
11%
4%
2nd TRANSITION 6 MONTHS
45%
31%
16%
8%
3rd TRANSITION 1 YEAR
35%
35%
19%
11%
4th TRANSITION 2 YEARS
27%
33 %
22%
18%
5th TRANSITION 4 YEARS
18%
33%
25%
26%
AVERAGE HEARING LOSS (500-2000 c p s)
CIRCLES INDICATE HEARING LEVEL IN db

Fig 5

state S_3 only 20% probability. The total number of early failures is subdivided almost equally among subjects with hearing losses of less than 50 db (states S_1 and S_2), and increases remarkably in subjects with hearing losses of more than 50 db (26%).

Since the transformation which occurred at the first transition tends to modify the numerical distribution of subjects, we apply the second transition matrix to the new matrix vector:

$$[40 \quad 12 \quad 16 \quad 8] \begin{bmatrix} 81 & 15.6 & 3.4 & 0 \\ 14.5 & 61.5 & 18.5 & 5.5 \\ 4 & 15.5 & 66.5 & 14 \\ 0 & 0 & 0 & 1 \end{bmatrix} = [34 \quad 16 \quad 14 \quad 12]$$

Six months after the operation, that is, at the second transition, the new distribution is as follows: 34 patients are still in state S_0 and are "successes", 16 patients make up state S_1, 14 state S_2, and 12 state S_3, all with probabilities which, as in the foregoing matrix, are expressed in percent for each degree of hearing loss. In particular, an individual who at the second transition was a "success" (hearing level above 30 db – state S_0), has an 81% probability of remaining a success, 15.6% of migrating to state S_1, that is, of getting worse, and 3.4% of migrating to state S_2 (hearing loss of 41–50 db).

Similarly, a subject who was in state S_1 after the operation (hearing level of 31–40 db), at the following transition has a 15.5% probability of further improvement and becoming a "success", 61.5% of remaining in state S_1, 18.5% of passing to state S_2, and 5.5% of migrating definitely to state S_3.

A subject who was in state S_2 after the operation has only a 4% probability of being a success, 15.5% of getting better, 66.5% of remaining in the pre-operative state, 14% of getting worse and passing to state S_3.

Subjects in state S_3, that is, with hearing losses of more than 50 db, have a zero probability of improving their hearing level.

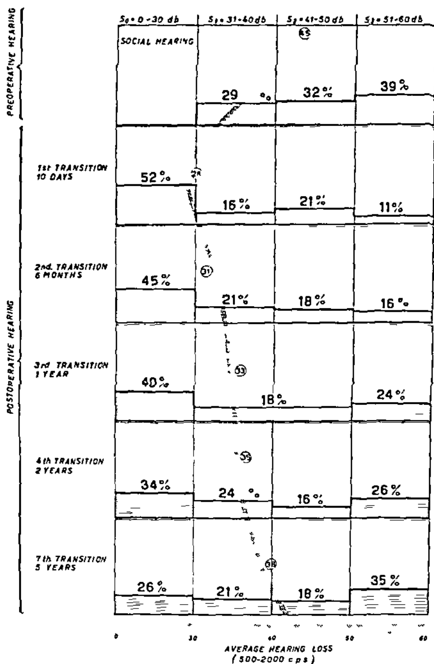
If we go on with our mathematical computations, we get:

$$[34 \quad 16 \quad 14 \quad 12] \begin{bmatrix} 81 & 15.6 & 3.4 & 0 \\ 14.5 & 61.5 & 18.5 & 5.5 \\ 4 & 15.5 & 66.5 & 14 \\ 0 & 0 & 0 & 1 \end{bmatrix} = [30 \quad 14 \quad 14 \quad 18] \quad \text{3rd transition}$$

$$[30 \quad 14 \quad 14 \quad 18] \begin{bmatrix} 81 & 15.6 & 3.4 & 0 \\ 14.5 & 61.5 & 18.5 & 5.5 \\ 4 & 15.5 & 66.5 & 14 \\ 0 & 0 & 0 & 1 \end{bmatrix} = [26 \quad 18 \quad 12 \quad 20] \quad \text{4th transition}$$

$$[26 \quad 18 \quad 12 \quad 20] \begin{bmatrix} 81 & 15.6 & 3.4 & 0 \\ 14.5 & 61.5 & 18.5 & 5.5 \\ 4 & 15.5 & 66.5 & 14 \\ 0 & 0 & 0 & 1 \end{bmatrix} = [24 \quad 18 \quad 14 \quad 22] \quad \text{5th transition}$$

$$[24 \quad 18 \quad 14 \quad 22] \begin{bmatrix} 81 & 15.5 & 3.5 & 0 \\ 14.5 & 61.5 & 18.5 & 5.5 \\ 4 & 15.5 & 66.5 & 14 \\ 0 & 0 & 0 & 1 \end{bmatrix} = [22 \quad 16 \quad 14 \quad 24] \quad \text{6th transition}$$



CIRCLES INDICATE HEARING LEVEL IN db

Fig 6

$$[22\quad 16\quad 14\quad 24]\begin{bmatrix}81 & 15.6 & 3.4 & 0\\ 14.5 & 61.5 & 18.5 & 5.5\\ 4 & 15.5 & 66.5 & 14\\ 0 & 0 & 0 & 1\end{bmatrix}=[20\quad 16\quad 14\quad 26]$$ th transition

At the seventh transition the patients distribution in the system remains unaltered the limit distribution was reached in the fifth post operative year Twenty subjects viz the 26 % of patients over 30 years who were operated retained their social hearing level reached through the mobilization operation In this group of patients the number of subjects belonging to state S_3 does not show the increment which is noticed in the former group (under 30 years) Fig 6 represents schematically the percentual consistency of each auditory state at each subsequent transition The dotted vertical curve (see circles) shows the behaviour of the average hearing level from before the operation to five years after it

CONCLUSIONS

1 Following extralabyrinthine mobilization over the neck or footplate total auditory rehabilitation may be expected in a fairly high number of cases (57 %) in the early post operative period

2 The percentage of rehabilitations is higher in the younger than in the older groups of patients (63 % vs 52 %) (Figs 5–6)

3 There is a critical pre operative hearing level which divides probable from improbable rehabilitations pre operative losses of less than 50 db give a 78 7 % probability of early rehabilitation whereas losses exceeding 50 db give the same probability in only 31 5 % of cases (Figs 3–4)

4 The probability of total rehabilitation for pre operative losses less than 50 db is nearly the same in the younger as in the older group of patients (77 5 % vs 77 %) whereas the same groups differ widely when losses of more than 50 db are considered (43 % vs 20 % total rehabilitations) (Figs 3–4)

5 The early post operative auditory gain shows at subsequent tests a clear overall tendency towards regression The initial average hearing level of 24 and 28 db obtained by operation (Figs 5 6) falls progressively so as to reach 37 and 38 db at the last transition considered where the system seems to have reached its new and ultimate equilibrium (see vertical dotted curves in Figs 5–6)

6 If the final distribution of the auditory states is taken into account (see last rows of Figs 5 6) it can be noted that a certain number of subjects still preserve total rehabilitation The stochastic process teaches us that there is every reason to assume that these rehabilitations may be considered definitive They are more numerous in the older than in the younger group of patients (26 % vs 18 %) It is interesting to note that our figures anticipated through a statistical study are nearly the same as those reported quite recently by Portmann and Guillon drawn by direct observation of long term results

7. The difference between long term auditory behaviour in the younger vs the older group of patients is more striking if we consider that early rehabilitations are 63 % in the former and 52 % in the latter. Therefore lasting results represent only 30.3 % of the initial results in the younger group of patients, whereas they are 50 % in the older group (Figs. 5, 6).

8. If the pre-operative losses of more than 50 db were excluded from the number of subjects for mobilization (we explained the reason in point 3), in the older group of patients lasting rehabilitations could be obtained in 39 % against 26 % of all operated cases. The same exclusion would only slightly alter the percentage of final rehabilitations in the younger group.

It may be safely inferred from all the foregoing considerations that extra-labyrinthine stapes mobilization over the neck or footplate is an unsatisfactory procedure in subjects of less than 30 years of age, whatever the clinical course of the disease and the pre-operative hearing level. As a matter of fact the percentage of lasting rehabilitations is too low to justify this surgical procedure, except under very special circumstances. In these subjects other procedures (fenestration or stapedectomy with interposition) may be more suitable.

On the other hand, patients of more than 30 years of age (and the older the better), if carefully selected on the basis of the clinical course of the disease (slowly progressing long-standing hearing loss) and of the pre-operative audiogram (not more than an average of 50-55 db loss for the speech frequencies), may prove very good subjects for classical mobilization operation, as they offer very good chances of excellent early results and about a 50 % probability of definitely preserving the initial rehabilitation.

In the feverish race among oto-surgeons going on today, in which very often the anxious research of new technical achievements takes away the necessary time for leisurely looking back at the road behind, an improved study of the results of each method employed will be of the greatest use.

It is our opinion that the classical stapes mobilization is worth while being attempted in selected cases, particularly since it has proved practically harmless in skilful hands.

We insist upon the principle of establishing a hierarchy of operations for the relief of otosclerotic deafness; each of these operations can well deserve its place in a well reasoned programme of surgical rehabilitation.

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RÉSUMÉ

Un critère nouveau d'élaboration statistique permet de prédire avec assez de précision les résultats éloignés de la mobilisation de l'étrier. Ce critère tient compte du fait essentiel que l'otosclérose, soit operée ou non, retient presque toujours un

caractere dynamique, et que seul un procede statistique dynamique peut eviter les erreurs, parfois grossiers, des methodes traditionels d elaboration des resultats On peut ainsi démontrer que l intervention de mobilisation directe ou indirecte n est pas justifiee dans les otoscleroses juvéniles au dessous de 30 ans, quoique les resultats immediats soient tres satisfaisants Elle garde encore au contraire une certaine valeur curative dans les formes tres lentement progressives de l âge mure L elaboration statistique dynamique des resultats peut etre recommandee comme critère de prevision valable pour la prediction du resultat fonctionnel dans les opérés suivant les dernieres techniques de chirurgie stapedienne

ZUSAMMENFASSUNG

Es wird ein neues statistisches Verfahren beschrieben nachdem man die nach langer Zeit erreichten Ergebnisse der Mobilisierungschirurgie richtig vorausgesagt hat Dieses Verfahren beachtet den dynamischen Gesichtspunkt der otosklerosen Krankheit, ob man operiert oder nicht es ist großtenteils fur die Unzuverlassigkeit der statistischen Angaben verantwortlich die sich auf die traditionellen Auswertungsmethoden grunden Es wird gezeigt, daß transcrurale oder Fußplattensteigbugel Mobilisierung in den fruhen und rasch fortschreitenden Stadien der Otosklerose eine ungerechtfertigte Operation ist obwohl sie bei langsam fortschreitender Krankheit im reiferen Alter eine gewisse Gültigkeit behalt, besonders wenn die Falle sorgfaltig ausgewahlt werden Diese statistische Methode scheint auch fur die Vorhersage der spateren Resultate der mehr avancierten Technik der Steigbugelchirurgie empfehlenswert zu sein

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HABITUATION, EFFERENCE AND VESTIBULAR INTERPLAY

I. Monaural Caloric Habituation

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Monaural habituation was produced in twelve subjects by repeated hot water irrigation and in twelve others by cold water irrigation. Two different groups of results were obtained. Group 1 exhibited directional preponderance towards the contralateral ear after hot water habituation and towards the ipsilateral ear after cold water habituation. Group 2 showed a reduced duration of nystagmus after both hot water and cold water irrigation of both ears. The group 1 results were attributed primarily to a modified efferent activity elicited from the reticular formation and secondarily to a change in the reciprocal activity of the two labyrinths. The responses in group 2, on the other hand, were ascribed to a more pronounced effect on the reticular formation, which thus modified the activity of the intervestibular communication.

During the course of habituation tests several of the subjects developed secondary nystagmus and two of them even spontaneous nystagmus. This is accounted for by the assumption that habituation disrupts the balanced activity of the two vestibular apparatuses, the disproportion reaching, in maximal cases, the threshold for spontaneous nystagmus.

Several instances of dysrhythmia were also observed and may be attributable partly to disproportion as above and partly to fluctuations of activity in higher and lower centers. The reasons underlying this theory are discussed.

Since the dysrhythmia impedes evaluation of the results from the velocity of the slow phase, the duration of nystagmus remains as the only reliable mathematical criterion of the response from the peripheral labyrinth.

Every living being from amoeba to man is subject to a perpetual stream of impulses, both exogenous and endogenous, which, via the mediation of various receptor organs, are conveyed to the central nervous system or its counterpart. Of the sum total of these impulses, however, only a few reach the level of consciousness. The central nervous system is continuously discriminating between stimuli received from different sources and competing for its attention. This attention is most likely to be concentrated either upon the most intense of the impulses or upon those which coincide with the existing focus of attention or that of the greatest immediate concern.

When attention is focussed in a specific direction, the incoming signals from other sense organs are inhibited via centrifugal pathways (Hernández Peón

1959). The phenomenon might be likened to a negative feedback which via the efferents continuously regulates the generation of impulses in the peripheral sense organs. A number of neurophysiologic studies have demonstrated that it is the reticular formation, among other structures, which controls both the inflow of impulses to the brain and the efferent outflow of signals to the peripheral organs (Hernández-Peón 1958, Hagbarth & Kerr 1954, Granit 1955).

The degree of attention is not, however, determined solely by the intensity with which the impulses are generated; it is also dependent on the frequency with which any given type of impulse reaches the central nervous system. Any sense organ subjected to repeated stimuli will sometimes exhibit progressively weaker responses; indeed, the impulses from it may subside completely. This form of response decline may be due to adaptation or to fatigue of the peripheral sense organ, or it may be attributable to centrifugal inhibition elicited from the central nervous system and designated by the neutral term "habituation" (Hernández-Peón 1959).

Numerous authors have shown that the vestibular organ too gives rise to habituation when exposed to repeated rotary or caloric stimuli of the same type (Dunlap 1925, Halstead *et al.* 1937, Loch & Haines 1946, Hallpike & Hood 1953, Hood & Pfaltz 1954, McCabe 1960, Lidvall 1961, Henriksson *et al.* 1961). Habituation is, however, an extremely diffuse concept originally applied in psychology to the loss of response to repeated sensory stimuli of all types and having no reference to its neurophysiologic mechanism. We felt, therefore, that it was worthwhile seeking the physiologic explanation of this phenomenon in the vestibular apparatus. In a previous investigation one of us (Fluur 1961) studied the influence of unilateral labyrinthine destruction on the activity of the intact labyrinth and found that this activity was facilitated under the influence of a central mechanism, probably mediated via the cerebellum. The present investigation was prompted by the desire to elucidate the influence of unilateral habituation on the interplay between the two labyrinths. The action of combined habituation tests will be reported in a subsequent paper.

MATERIAL AND METHODS

The investigation comprised 24 subjects with no history of disturbances of balance. Prior to habituation all of them underwent caloric tests *ad modum* Fitzgerald & Hallpike (1942), both as a check to ensure that they had normal labyrinthine functions and to secure initial values for comparison with the end results after habituation. In order to obviate incipient habituation at the initial test, the sequence of tests was so arranged that each successive irrigation produced eye movements in the direction opposite to that in the preceding test.

Twelve of the subjects then formed one series for monaural hot water habituation (44° C) while the other twelve formed another series for monaural

cold water habituation (30°C) For purposes of habituation each subject was irrigated with hot or cold water in one ear for 30 seconds whereupon the nystagmus was studied On cessation of eye movements the recording was continued an additional two minutes for detection of secondary nystagmus Every five to eight minutes the same ear was subjected to further irrigation accompanied by recording of the nystagmus In general the habituation series comprised between eight and twelve irrigation tests

When maximal habituation had been attained a final caloric test was conducted and the subject examined for the presence of any spontaneous or secondary nystagmus

An electronystagmographic recording method was employed electrodes being attached to the outer canthus of each eye The reference electrode was placed in the center of the forehead The recorder was an eight channel nystagmograph (Schwarzer) permitting registration of the rapid and the slow phases of nystagmus on separate channels

RESULTS

It will be seen from Tables 1 and 2 that at the very first test *ad modum* Fitzgerald and Hallpike major intra individual variations occurred both in duration and in frequency on comparison of the right and left responses to hot water and cold water irrigation This behavior however is typical of the relevant vestibulo ocular reflex arc and cannot be attributed to a primary habituation tendency the sequence of tests being such that the direction of nystagmus was always opposite to that in the preceding test Biologic investigations of this type do not lend themselves to statistical analysis for several different centers are implicated in the responses In comparing the initial and final results of caloric irrigation it is necessary to assume that under unvarying *neurophysiologic conditions sensory organs will normally show an unvarying* response It is important therefore when evaluating frequency and duration to take only a given initial result at a given irrigation temperature in a given ear, since the examination is concerned precisely with the influence of the central nervous system on the peripheral generation of impulses

Even when the rhythm was fully normal at the initial test the majority of subjects exhibited during the development of habituation varying disturbances of rhythm in the form of total temporary inhibition the duration of which varied both intra and inter individually Sometimes no complete block occurred but simply a partial inhibition with a diminution of amplitude as well as rises or falls in the frequency of nystagmus Owing to this interplay between inhibition and facilitation the intensity of which frequently increased with the progress of habituation it was quite impossible to evaluate the curves merely by recording the usual characteristics of nystagmus i e number of eye movements amplitude duration and maximum rate of the rapid or the slow phase Although we did at first evaluate the curves on the basis of these characteristics as the investigation proceeded we were forced to apply quite

TABLE 1 *Durations of nystagmus before and after habituation of right ear to 44°C*

		Duration 30°C		Duration 44°C	
		Prehab	Posthab	Prehab	Posthab
		Group 1			
H 1	R	132	148	130	44
	L	121	54	102	120
H 2	R	178	178	124	82
	L	178	76	177	184
H 3	R	130	147	140	70
	L	124	40	138	180
H 4	R	170	192	154	104
	L	180	112	152	194
H 5	R	188	330	184	167
	L	201	206	173	260
H 6	R	102	142	134	68
	L	94	74	136	220
H 7	R	122	158	134	122
	L	134	110	115	186
H 8	R	194	224	140	130
	L	220	110	178	194
H 9	R	184	sp nyst left	202	142
	L	238	200	270	sp nyst left
H 10	R	132	134	122	119
	L	136	114	126	135
		Group 2			
H 11	R	183	149	110	50
	L	140	100	150	120
H 12	R	208	144	134	104
	L	234	102	200	178

different criteria more consistent with neurophysiologic practice—as in the study of electroencephalograms and electrocardiograms—that is to say, we not only considered the general appearance of the curve but meticulously studied its various details. It emerged that only the duration of nystagmus constituted a fairly reliable numerical criterion of the stimulation results; other changes could not be expressed in figures but required verbal exposition. Since, however, space does not permit of this mode of presentation, we have elected to record the results partly in tables and curves, and partly in the form of occasional descriptions of details of the curves.

Ten of the subjects who underwent hot water habituation exhibited very characteristic changes in the responses of the two labyrinths (Table 1). Since

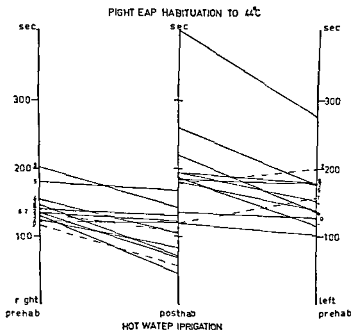


FIG 1 Durations of nystagmus after hot water irrigation of right and left ear before (on the left and right vertical lines) and after (on the middle vertical line) right ear habituation to 44 C Group 1 (continuous line) Nystagmus duration decreases for right ear but increases for left ear after habituation Group 2 (broken line) Nystagmus duration decreases for both ears

they all responded in the same way they were assigned to a group 1 with the following results Repeated hot water irrigation in the right ear led to a progressive decrease in the duration of nystagmus but at no time to extinction of the response Post habituation testing by hot water irrigation (Fig 1) showed a reduction both of duration and of frequency and amplitude Cold water irrigation (Fig 2) on the other hand produced in all cases nystagmus of longer duration than that prior to habituation Hot water irrigation of the non habituated contralateral ear also resulted in nystagmus of prolonged duration whereas cold water irrigation gave a shorter duration

Apart from these ten cases there were two subjects whose responses differed from those in group 1 and who were therefore called group 2 Following habituation both of them had considerably shorter durations of nystagmus both for hot water and for cold water irrigation of the right as well as of the left ear Furthermore post habituation cold water irrigation was followed by long latent periods on both sides after which the nystagmus frequently started with a low amplitude then increased both in frequency and in amplitude The latent periods varied between 10 and 92 seconds after the termination of irrigation

Cold water habituation which was also produced in twelve subjects gave the following results (Table 2) All subjects exhibited declining responses to repeated cold water irrigation in the right ear (Fig 3) and three of them

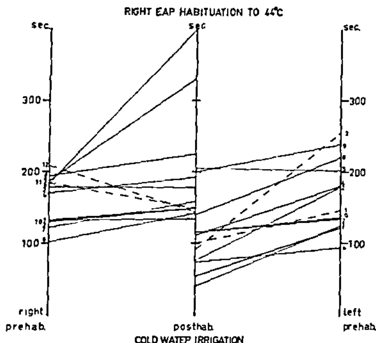


Fig. 2. Durations of nystagmus after cold water irrigation of right and left ear before (on the left and right vertical lines) and after (on the middle vertical line) right ear habituation to 44°C. Group 1 (continuous line): Nystagmus duration increases for right ear but decreases for left ear after habituation. Group 2 (broken line): Nystagmus duration decreases for both ears.

showed almost total extinction of the nystagmus. As regards the post habituation behavior two groups of responses were also obtained here. Group 1 comprised eight subjects in whom hot water irrigation of the right ear was followed by a prolonged duration of nystagmus (Fig. 4). We observed in five cases a heightened frequency and a lower amplitude, alternating with periods of lower frequency and higher amplitude. Several curves were almost devoid of nystagmus, revealing only a coarse waved, undulating movement interrupted by occasional nystagmus deflections. Cold water irrigation of the non habituated left ear likewise gave a longer duration, whereas caloric irrigation of that ear gave a shortened duration.

Group 2, comprising four subjects, showed in the post habituation tests bilateral shortening of the nystagmus duration after both cold water and hot water irrigation.

During the course of habituation a number of the subjects developed characteristic secondary nystagmus after each irrigation. Thus, irrigation of the left ear with water at 30°C or of the right ear with water at 44°C following hot water habituation resulted in secondary nystagmus. The latter was directed to the left in five subjects and to both the right and the left in three. Indeed, one of the subjects even showed spontaneous nystagmus towards the left.

Following cold water habituation five subjects had secondary nystagmus

Table 2 *Durations of nystagmus before and after habituation of right ear to 30 C*

		Duration 30°C		Duration 44°C	
		Prehab	Posthab	Prehab	Posthab
		Group 1			
C 1	R	1[illegible]0	126	136	162
	L	164	208	140	120
C 2	R	134	110	142	171
	L	138	150	218	160
C 3	R	186	128	143	144
	L	157	184	154	108
C 4	R	145	96	154	187
	L	82	140	184	166
C 5	R	1[illegible]0	157	98	134
	L	158	180	198	158
C 6	R	228	166	212	230
	L	154	170	134	120
C 7	R	330	218	194	sp nyst right
	L	258	sp nyst right	216	156
C 8	R	118	60	96	160
	L	160	1[illegible]0	208	92
		Group 2			
C 9	R	126	28	148	120
	L	110	88	140	62
C 10	R	138	62	144	90
	L	162	77	124	111
C 11	R	212	148	116	96
	L	108	104	140	92
C 12	R	1[illegible]0	104	13[illegible]	94
	L	140	92	130	108

towards the right on irrigation of the right ear at 30°C or of the left ear at 44 C One of these subjects exhibited spontaneous nystagmus towards the right

In the course of habituation tests the nystagmus responses of several subjects became increasingly dysrhythmic after each irrigation Such periodic inhibition and facilitation developed during cold water habituation in six subjects and during hot water habituation in nine In the post habituation caloric tests the nystagmus was dysrhythmic only at specific irrigation temperatures Following hot water habituation the nine subjects mentioned above had this dysrhythmia after irrigation at 30° in the right ear and after irrigation at 44° in the left ear Cold water habituation on the other hand gave rise to an irregular dysrhythmia which in three of the subjects followed

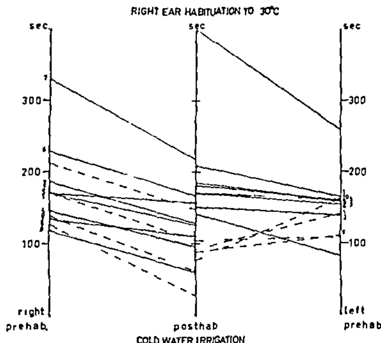


Fig. 3. Durations of nystagmus after cold water irrigation of right and left ear before (on the left and right vertical lines) and after (on the middle vertical line) right ear habituation to 30° C. Group 1 (continuous line): Nystagmus duration decreases for right ear but increases for left ear after habituation. Group 2 (broken line): Nystagmus duration decrease in both ears.

cold water irrigation of the left ear or hot water irrigation of the right. In three cases we observed dysrhythmia on hot water irrigation of both the right and the left ear and in two cases only after hot water irrigation of the left ear. In the subjects with dysrhythmia after tests on both sides, irrigation of the *right ear yielded a nystagmus pattern characterized by periodic inhibition* sometimes associated with a slow lateral deviation of the eyes and followed by the rapid phase after a few seconds. Stimulation of the left ear, on the contrary, elicited nystagmus with periods of normal rhythm interrupted by series of nystagmus deflections of very high frequency and low amplitude. The difference between the respective frequencies was sometimes as great as 1 : 4. In two cases we observed no dysrhythmia proper but merely a general increase in frequency coincident with a lower amplitude.

DISCUSSION

The investigation has shown that habituation produced by monaural irrigation with hot or cold water gives rise to two different types of responses, which are here termed group 1 and group 2. In group 1 repeated hot water irrigation led to directional preponderance *away from* the habituated ear, whereas cold

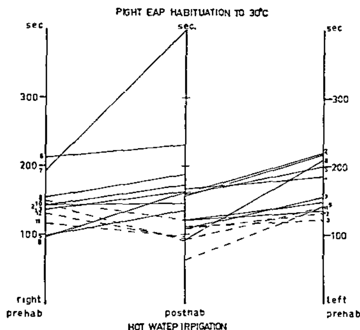


FIG 4 Durations of nystagmus after hot water irrigation of right and left ear before (on the left and right vertical lines) and after (on the middle vertical line) right ear habituation to 30 C Group 1 (continuous line) Nystagmus duration increases for right ear but decreases for left ear after habituation Group 2 (broken line) Nystagmus duration decreases in both ears

water habituation was associated with preponderance *towards* the irrigated ear In group 2 both hot water and cold water habituation resulted in a bilateral depression of the post habituation reactivity to both hot and cold water

On monaural habituation the vestibular organ of the irrigated ear thus underwent such changes that it showed either a better or a poorer response to the subsequent test at an irrigation temperature producing cupula deviation opposite to that observed during habituation Henriksson *et al* (1961) who reported similar comparisons in the cat found no corresponding changes in that animal

The non habituated ear also presented changes in the mode of response both after hot water and after cold water habituation Such transfer was demonstrated long ago by Dunlap (1925) who on testing the non habituated ear, observed a marked reduction of nystagmus Henriksson *et al*, too, studied this phenomenon and found that transfer is demonstrated mainly when the non exposed ear is irrigated with equivalent stimuli in several animals however both eye velocity and duration of nystagmus were somewhat diminished when tested with nonequivalent stimuli These observations fully accord with our own findings in group 2 The absence, in Henriksson s studies of responses equivalent to those in our group 1 may be attri

butable to the fact that in the cat, notwithstanding its seemingly placid exterior, caloric tests of this type produce a nervous shock (arousal reflex) leading to general abrogation of peripheral activity under the influence of impulses from higher centers.

The numerous observations made in our investigation may at first sight appear confusing, yet all of them can be readily accounted for on the basis of known anatomic and neurophysiologic data. The sensory cells of the semicircular ducts have, at rest, a specific electric potential difference in relation to the environment. By virtue of the electrolytic activity this potential difference tends to be broken down by a depolarization pressure which in leads from the vestibular nerve can be recorded in the form of a spontaneous electrical activity. Under the influence of cupula deviation in one direction or the other, this potential difference may be so altered that the number of discharges from the sense organ either increases or decreases. Ampullopetal endolymph currents in the horizontal semicircular ducts give rise to depolarization attended by an increase in the number of centrally propagated impulses. Ampullofugal currents, on the other hand, give rise to hyperpolarization, whereby the activity falls towards zero (Lowenstein & Sand 1936, Gernandt 1949, Ledoux 1949, Lowenstein 1950, 1956).

The activity in the sensory cells, however, is not governed solely by the cupula deviations. Rasmussen & Gacek (1958) and Gacek (1961) have shown that efferent fibers from the lateral vestibular nucleus pass to the peripheral labyrinth. Wersäll (1956) as well as Engström (1958) have identified, in the latter structure, granulated nerve terminals which, in their view, represent a form of efferent innervation. Although our knowledge of the exact function of the efferent system is still very imperfect, there is much to suggest that it exerts the same influence on the vestibular organ as on the cochlea (Fex 1962). This being the case, an increase of the efferent activity would lead to hyperpolarization of the cell membrane accompanied by inhibition of the stream of impulses from the sensory cells to the central nervous system. Depression of the efferent activity, on the other hand, would result in loss of this hyperpolarization pressure, which normally is always present to a certain extent. In consequence, the depolarization pressure from the sensory cells would increase, and this in turn would result in augmented spontaneous activity and intensified impulse production on stimulation. It is this intimate interplay between afferents and efferents that might account for all the results obtained in the present investigation.

With repeated hot water irrigation of one ear the duration of nystagmus is progressively shortened. The explanation of this phenomenon may be either that the depolarization in the peripheral labyrinth declines with each irrigation, or that the efferent activity increases with each irrigation, thus giving rise to peripheral hyperpolarization. In each case the impulse production will be impaired. Reduced depolarization, however, would be tantamount to exhaustion of the depolarization capacity of the sensory cells, i.e. fatigue. Characteristic of fatigue is the fact that the sense organ, after a brief rest

recovers its normal functional capacity Several authors have shown that this form of response decline—which occurred in our investigation—is not fatigue but is attributable to habituation to a specific stimulus Hence the response decline is most likely due to a gradual diminution of the depolarization pressure in the peripheral labyrinth under the influence of a mounting efferent activity leading to hyperpolarization of the cell membrane As a result both the spontaneous activity and the action potentials from the sensory cells are depressed or even totally suppressed In this way the hyperpolarization assumes the character of a counter electromotor force which increases with each irrigation and whose purpose is to depress the responses of the sensory organ to a specific stimulus

Inasmuch as the hyperpolarization under the influence of the efferent activity, is at a high level ampullofugal endolymph currents result in an additional hyperpolarization which is substantially greater than it would have been without the efferent influence Because of this absolute increase in the hyperpolarization pressure the difference between the right and left semicircular duct activity will be greater than that prior to habituation—particularly as the spontaneous activity of the contralateral labyrinth also increases as will be discussed later on Since the intensity of nystagmus is determined by the difference between the activities of the two labyrinths cold water irrigation of the ear habituated with hot water should accordingly give rise to nystagmus of longer duration—as indeed was found in the present group 1 This result also lends support to the view (Fluur 1960) that the activity of the contralateral vestibular organ is co determinant for the responses to cold water irrigation

The habituation with hot water in group 1 also produced a change of polarity in the contralateral non habituated labyrinth—but here the change was in precisely the opposite direction Apparently there is a diminution of the efferent activity accompanied by an increase of the peripheral depolarization pressure This results in an augmented spontaneous activity and on stimulation with hot water an increase of the action potentials as compared with the pre habituation values The investigation demonstrated that this is indeed the case since hot water irrigation of the contralateral ear after habituation gave a longer duration of nystagmus Cold water irrigation of the same ear gave contrariwise a shorter duration of nystagmus firstly because the increased depolarization pressure impeded the peripheral hyperpolarization associated with ampullofugal endolymph currents and secondly because the nuclear activity on the habituated side diminished under the influence of the ipsilateral hyperpolarization The investigation accordingly yielded results in full accord with the behavior observed after unilateral labyrinthectomy (Fluur 1961)

Although repeated cold water irrigation also gave rise to habituation the latter was more difficult to produce than with hot water The results in group 1 were precisely the opposite to those of hot water habituation Repeated cold water irrigation apparently leads to declining ipsilateral efferent activity

Thus there is loss of inhibition attended by an increased depolarization p sure with an augmentation of both spontaneous activity and impulse prod tion with ampullopetal endolymph currents This accounts for the declir responses to repeated cold-water irrigation The hyperpolarization stemm from the cupula deviation cannot manifest itself effectively because of elevated depolarization level As a result ipsilateral hot-water irrigation foll ing habituation produces nystagmus of longer duration

The contralateral labyrinth not habituated with cold water showed a re suggesting that the efferent activity on that side undergoes an increase whi according to the aforegoing discussion, serves to augment the periphe hyperpolarization pressure. Because of this, hot-water irrigation fails depolarize the sensory cells as effectively as before, and hence the impu production is attenuated and the duration of nystagmus shortened Co water irrigation, on the other hand, results in a longer duration of nystagm the hyperpolarization being even more effective than it was prior to habit tion

In two of the present subjects the habituation led to spontaneous nystagn the direction of which was opposite to that observed in the course of habituation tests Furthermore, secondary nystagmus was noted in seve subjects These findings suggest that during the course of habituation peripheral labyrinthine activity is so modified by efferent influence that normal equilibrium between the vestibular nuclei is disrupted This i balance remains constant for the duration of habituation, though very oc sionally it may become so pronounced as to reach the threshold of spon neous nystagmus In general it is demonstrable only during that phase, f lowing the subsidence of primary nystagmus, in which the spontane polarity level of the sense organ falls briefly under normal (Lowenstein Sand, 1940 Eckel, 1954, Ledoux, 1958) It is, presumptively, the same i *balance that is responsible for the dysrhythmia which occurs during* t course of habituation tests The variability of the dysrhythmia can be a counted for by the assumption that the conflict of impulses is subject changes in the activity of both higher and lower centers and hence is read affected by such factors as preoccupation with mathematical tasks (Lidv 1961), the desire to micturate, or painful sensations in any part of the bo (personal observations)

This brings up the important question as to the mechanism where habituation is produced In the opinion of Halstead *et al* (1937) habituatior controlled by the cerebellum since it cannot be elicited with equal facility cerebellectomized animals Other authors have expressed the view that it elicited from higher subcortical or cortical centers (Dunlap, 1925 Loch Haines, 1946, Hood & Pfaltz 1954, McCabe, 1960) The present investigati has disclosed a reciprocal relationship of the horizontal semicircular can not only in regard to the influence of cupula deviation upon the sensory ce but also with respect to the interplay of the efferent influence upon the pe pheral labyrinths A number of investigations reported in the literature su

gest that this reciprocity is controlled via the caudal pole of the fastigial nucleus in the cerebellum. This particular question has been discussed in a previous article (Fluur 1961). In all probability this habituating feedback mechanism is elicited from the reticular formation, which, by augmenting or depressing the efferent activity, influences the polarity level in the sensory cells of the peripheral labyrinth and, perhaps, in the cells of the vestibular nuclei too. The reciprocity is likely, moreover, to be a secondary phenomenon which either is induced directly from the reticular formation or, more probably, is mediated via the cerebellum as indicated above. A direct communication between the vestibular nuclei of the two sides via secondary vestibular fibers is another possibility that cannot be precluded (Rasmussen, personal communication). There are several factors which suggest that habituation is produced from the reticular formation. One of them consists of the results in group 2, where both labyrinths showed, after habituation, a shorter duration of nystagmus both for cold and for hot water. The explanation may be that the reciprocity occurs only when the reticular formation is moderately active, whereas a very high or very low level of activity in that center produces an effect on both labyrinths simultaneously—an effect in the direction either of hyperpolarization or of depolarization. Cold water habituation is associated with a bilaterally increased depolarization pressure, manifested in very slight nystagmus on bilateral cold water irrigation—an observation that was made in our investigation. Here, contrary to expectation, hot water irrigation did not result in a longer duration of nystagmus—a finding that might be accounted for by factors to be discussed later on. Hot water habituation, in contrast, leads of course to hyperpolarization of both labyrinths, entailing prolonged latent periods and attenuated nystagmus on subsequent cold water irrigation both of the right and of the left ear. Indeed, we were able to verify this in two of our subjects. That bilateral habituation can be induced has been demonstrated by, e.g., McCabe (1960), who interpreted his results as an effect of the reticular formation. Such an interpretation gains added credence from the fact that even a cerebellectomized animal can be habituated, albeit not so readily as a normal animal (Halstead *et al.* 1937). Additional corroboratory evidence can be found in the observation that compensation following unilateral labyrinthine destruction, which also constitutes habituation of a sort, can be established in spite of cerebellectomy (*vide* Fluur 1960).

Certain investigatory results indicate that the changes in polarization which attend habituation are not only mediated to the vestibular apparatus but also affect the other synapses in the vestibulo-ocular reflex arc. In this investigation hot water habituation gave rise to a higher hyperpolarization pressure in the right ear. Post-habituation hot water irrigation of the right ear might thus be expected to produce a nystagmus response of lower frequency, since the peripheral vestibular apparatus under these circumstances transmits fewer impulses to the central nervous system. Traces of this are detectable in the curves from nearly all of the subjects who underwent hot water habituation, although these curves also show a considerably lower amplitude, the explana-

tion of which may be that the reticular formation augments both the efferent activity in the labyrinth and the activity in Darkshewitsch's nucleus. The ability of this nucleus to hyperpolarize the cell membranes of the ocular muscle nuclei and thereby elicit the rapid phase of nystagmus would thus be increased (Fluur 1962).

In the case of cold water habituation we obtained a higher depolarization pressure in the right labyrinth. In these circumstances the post habituation hot water irrigation will serve to raise the number of impulses passing to the central nervous system and a nystagmus response of higher frequency might thus be expected. We did in fact observe this in five subjects though in general these cases also exhibited a lower amplitude alternating with periods of lower frequency and higher amplitude. Occasionally there appeared only coarse waved undulating eye movements. A possible explanation is that the greater number of impulses from the periphery reach an oculomotor center whose hyperpolarizing component—Darkshewitsch's nucleus—has a depressed activity and thus requires a far greater addition of impulses in order to break down the depolarization pressure and elicit the rapid phase. If the activity from the reticular formation is not regular but variable the recorded curves will show a higher frequency and low amplitude when the activity is high but a low frequency and high amplitude when the activity is low. This alternating activation and inhibition in the reticular formation is very likely responsible for the dysrhythmia generally observed after habituation. This dysrhythmia can assuredly be elicited via impulses from a number of different centers both at cerebral and at spinal level.

CONCLUSIONS

1. The activity of the vestibulo ocular reflex arc is regulated not only by cupula deviations but also by an efferent mechanism both from the reticular formation and from the cerebellum, as well as possibly via secondary vestibular fibers directly from the contralateral vestibular organ.

2. An increase or decrease of the afferent impulses from one horizontal semicircular duct affects the contralateral efferent system.

3. The intervestibular communication is presumptively subject to higher centers which, on intensive stimulation, suppress its activity.

4. Habituation appears to affect several stations in the vestibulo ocular reflex arc: the peripheral labyrinth, the intervestibular communication, the reticular formation and an oculomotor center.

5. *Directional preponderance is due to a central difference in the activity* of the right and the left vestibular organs. Its eliciting mechanism may be both central and peripheral.

6. Secondary nystagmus is a manifestation of a difference in activity between the right and the left labyrinths, albeit not sufficiently pronounced for spontaneous nystagmus. It appears to be elicited by the same mechanism as that for directional preponderance.

7 Dysrhythmia may be caused by both central and peripheral factors

8 The velocity of the slow phase of nystagmus is not only regulated by a peripheral mechanism but is dependent to a large degree on the efferent activity as well as the activity in the oculomotor centers

9 As long as a difference in activity exists between the right and left horizontal semicircular ducts there will also be a persistent tendency to eye deviation or nystagmus During this period the velocity of the slow phase may vary substantially under the influence of the reticular formation and the cerebellum The duration of nystagmus appears therefore to reflect a persistent difference in peripheral vestibular activity

ZUSAMMENFASSUNG

Mit wiederholten monauralen kalorischen Spulungen mit warmem Wasser wurden zwolf Personen angewohnt (habituiert) und noch zwölf mit Spulungen mit kaltem Wasser Man erhielt zwei verschiedene Resultatgruppen In Gruppe 1 erhielt man nach Gewohnung mit warmem Wasser eine Nystagmusbereitschaft zum kontralateralen Ohre hin und nach Gewohnung mit kaltem Wasser zum ipsilateralen Ohr hin In Gruppe 2 erhielt man auf beiden Ohren eine abnehmende Dauer des Nystagmus fur sowohl kalte wie warme Spulung Es wurde angenommen dass Gruppe 1 primar auf eine veranderte Aktivitat der Efferenten, von Formatio Reticularis ausgelost, und sekundar auf eine Veranderung der Reziprozitat der beiden Labyrinthen ankomme Man vermutete dass die Antworten der Gruppe 2 auf eine mehr ausgesprochene Beeinflussung auf Formatio Reticularis ankomme die dann die Aktivitat der intervestibularen Kommunikation verandert

Wahrend der Gewohnung entwickelte sich in mehreren Fallen ein Sekundarnystagmus und in zwei Fallen auch ein Spontannystagmus Man glaubte es komme darauf an dass die Gewohnung zu einer Disproportion der Aktivitat der beiden Vestibularisapparaten führt die in maximalen Fallen die Schwelle des Spontannystagmus erreicht

Man fand auch mehrere Falle mit Dysrhythmie die teils auf oben genannte Disproportion teils auch auf Fluktuationen der Aktivitat hoheren und niederen Zentren anzukommen schienen

Man vermutet dass die Gewohnung den ganzen vestibulo ocularen Reflexbogen beeinflusst

Die Dysrhythmien führen Schwierigkeiten mit sich die Resultate nach Geschwindigkeit der langsamen Phasen zu beurteilen wodurch die Dauer des Nystagmus als das einzige mathematische Mass der Reaktion der peripheren Labyrinthen übrig bleibt

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LOW LEVEL STIMULATION IN THE DIFFERENTIATION OF MIDDLE EAR PATHOLOGY[1]

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A 20-db SL tone was presented at 4000, 1000 and 500 cps respectively for three minutes. Following each exposure subjects traced threshold recovery to the stimulating tone for five minutes on a Békésy type automatic audiometer. Forty six subjects with aural conductive disorders and 23 subjects with normal hearing were evaluated.

On the basis of this investigation the following conclusions were considered tenable:

1. Epstein and Bower's data suggesting greater Temporary Threshold Shift (TTS) over time for conductively involved ears than for normally hearing ears were confirmed.

2. Four thousand cps produced the greatest TTS and provided the most differentiation between normal and conductive ears particularly by the fifth minute of recovery.

3. The amount of TTS was positively correlated with both extent of hearing loss and duration of hearing loss regardless of the specific etiology.

4. Although the Initial Temporary Threshold Shift differentiated normal ears from conductively involved ears, the measure provides uncertainty for clinical diagnosis due to the considerable overlap between the groups.

5. The use of TTS for clinical audiometric identification of conductive hearing loss appears feasible.

6. The measure of variability change was not as clear cut as TTS in differentiating conductive from normally hearing subjects.

INTRODUCTION

The use of low level post-stimulatory fatigue in differentiating aural pathology has been reported by Palva (17) and Epstein & Bower (8). Palva employed a 30 db SL pure tone stimulus and traced recovery over two minutes for the exposure tones of 4000, 2000, 1000 and 500 cps respectively on a Békésy type audiometer. He concluded:

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> In diagnosis the use of post stimulatory fatigue does not seem helpful beyond separating some perceptively deaf cases from conductive deafness. Many recruiting subjects show normal recovery and some show abnormally great fatigue. In conductive deafness, as well as in normal ears, recovery is as a rule rapid but in some cases there may be abnormal sensitivity to continuous stimulation (17, p. 237).

Epstein and Bower utilized a 20 db SL tone in order to differentiate among four etiological groups, namely, presbycusic, noise trauma, conductive (otosclerotic) and normal. Their subjects were exposed to 4000, 2000, and 1000 cps respectively for three minutes. Each subject traced recovery continuously for six minutes. The otosclerotic group displayed the greatest temporary threshold shift (TTS) and the slowest recovery for each test frequency. This was particularly apparent for 4000 and 1000 cps. The normal hearing group followed a similar trend but did not shift as much nor recover as slowly. The two sensory neural groups showed the least amount of fatigue and the most rapid recovery. The fact that low level stimulation differentiated the Otosclerotic group from the Normal Hearing group is of considerable interest. Epstein and Bower note:

> The differences noted between the conductive loss group and the normal hearing group may be due to the fact that only otosclerotic losses were included in the conductive group. It may be that other conductive pathologies would not be so differentiated from the normal hearing responses and it can be tentatively suggested that the particular behavior noted here is capable of separating otosclerosis from other conductive involvements.

The present investigation undertook to replicate the study of Epstein and Bower on a variety of conductively involved hearing losses, including otosclerotics as well as a normal hearing group. It was felt that an analysis of the response of various types of conductive pathologies to low level stimulation would determine whether this technique is capable of providing psychoacoustic identification of the presence of particular middle ear lesions.

EXPERIMENTAL PROCEDURE

Instrumentation

A Grason Stadler Bekesy type automatic audiometer, Model E800, was employed for plotting thresholds before and after stimulation. The attenuator pen combination operated at an average rate of 2.4 db per second. The subjects were tested in a 1200 series Industrial Acoustics Company sound insulated room. To aid the subjects in accurately carrying out the test procedure, a switch in the control room enabled the experimenter to light a red lamp labelled "rest" and an amber light labeled "alert". An electric timer

TABLE 1

Group	N	Age	Male	Female	Mean Békésy threshold 500	1000	4000	Duration of loss (months)
Normal	23	20	10	13	−16	−12	−4	0
Otosclerotic	23	34	8	15	40	43	41	115
Non Otosclerotic Conductives								
Serous[a]	8	19	2	6	16	20	28	10
Hyperplastic[b]	9	25	2	7	36	38	34	119
Miscellaneous[c]	6	30	4	2	45	39	45	175
	23	24	8	15	32	32	35	101

[a] Serous Otitis Media refers to watery fluid in the middle ear cavity with an intact tympanic membrane

[b] Hyperplastic Otitis Media refers to adhesive processes in the middle ear with or without an intact tympanic membrane

[c] Miscellaneous (*a*) Middle ear condition characterized by a moderately viscous foul smelling discharge and a perforated tympanic membrane (chronic purulent Otitis Media N 3 (*b*) Dry middle ear cavity following the removal of the malleus incus and mastoid air-cells (post-operative radical mastoidectomy N = 3)

appropriately extinguished the amber signal and turned on a green light labeled listen simultaneously with the introduction of the search tone

Subjects

The 46 individuals who comprised the experimental group were selected on the basis of a significant air bone gap otological examination results consistent with conductive pathology and speech discrimination scores for W 22 monosyllabic word lists of better than 90 per cent In addition it was required that there be no indication of sensory neural overlay suggested by either health or work history

The subjects were divided into three major disorder groups on the basis of the final diagnosis (see Table 1)

Fig 1 shows the mean thresholds for air and bone conduction for the Otosclerotics and for the Non Otosclerotic Conductives and air conduction thresholds for the Normal Hearing subjects

Test Administration

Preliminary instructions and practice session

Following a standard pure tone and speech audiometric battery each subject received training for the low level post stimulatory fatigue test A 4000 cps practice tone was presented to the subject s test ear for one minute

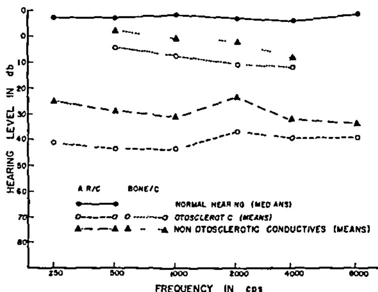


Fig 1 Composite standard pure tone audiogram for the Normal Hearing Otosclerotic and Non Otosclerotic Conductive subjects

If the individual did not follow the directions he was reinstructed The practice session was not begun until the investigator was satisfied that the subject understood the directions

The order of frequencies tested was 4000 2000 and 1000 cps to avoid the possibility of a cumulative fatigue effect (6 7 19) The subject was exposed to the same frequency at 20 db above the previously determined threshold Threshold was considered the mid point between the upper and lower excursions of the Bekesy trace The stimulating tone was presented continually for a period of three minutes immediately after which the subject traced his changing threshold for five minutes This technique yielded a continuous measure of the threshold recovery pattern over time

The test instructions and procedures were then repeated for 1000 and 500 cps tones in that order No preliminary practice was given after the first (4000 cps) frequency The entire procedure was administered to one ear only

Scoring

The following measures were of particular concern in this investigation

(1) Initial temporary threshold shift (ITTS) First response point following cessation of stimulation

(2) Temporary threshold shift (TTS) The midpoint of the excursion about threshold measured at 15 30 45 seconds one two three four and five minutes after cessation of the exposure tone This value was considered the decibel difference between the post and pre stimulation thresholds

(3) Variability change (VC)[1] This was defined as the difference between the mean amplitude of the envelope about the pre stimulation threshold, expressed in decibels, and the mean of comparable 30 second segments of the first and second minutes following stimulation

RESULTS

Initial Temporary Threshold Shift

The analysis of variance technique was utilized to study the differences between means of the measure of Initial Temporary Threshold Shift (ITTS) A design for repeated measurements on several independent groups (5) was employed to consider test Frequency by aural Disorder The time at which ITTS was measured was dependent upon the time at which the tone became audible following exposure In all cases ITTS was measured between three and 14 seconds after cessation of the stimulating tone dependent on the amount of threshold shift The mode was between four and eight seconds following stimulation, that is about 10 to 20 db shift

TABLE 2 *Analysis of variance between means of the Normal, Otosclerotic and Non Otosclerotic Conductive groups for the Initial Temporary Threshold Shift*

Source of variation	df	Mean square	F	Significance level
1 Disorder (D)	2	87 48	3 62	05
2 Frequency (F)	2	70 44	6 32	01
3 $D \times F$	4	13 92	1 25	NS
4[a] S/D	66	24 16		
5 $F \times S/D$	132	11 15		

[a] Line 4 is the error term for line 1 and line 5 is the error term for lines 2 and 3 S/D is the within groups variance

Table 2 summarizes the statistical analysis for the ITTS measure The significant F value between Disorders indicates that the differences in Initial Temporary Threshold Shift between the Normal Hearing Otosclerotic and Non Otosclerotic Conductive groups could not likely have arisen by chance The Otosclerotic group had the greatest amount of Initial Temporary

[1] VC may be expressed

$$VC = \left(\frac{30}{NEAT} \times AR\right)_{pre} - \left(\frac{30}{NEAT} \times AR\right)_{post}$$

where NEAT represents the total Number of Excursions About Threshold for the specified 30-second period and AR is the Attenuation Rate in db second

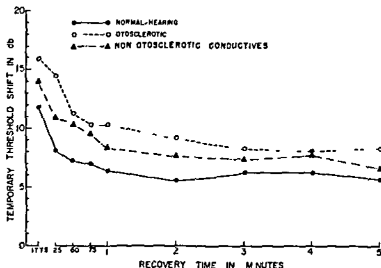


Fig. 2. Mean Temporary Threshold Shift for 500 cps over recovery time for the Normal Hearing, Otosclerotic, and Non Otosclerotic Conductive Groups.

Threshold Shift followed by the Non Otosclerotic Conductives who showed consistently less shift than the Otosclerotic group and the Normal group which shifted the least of the three. That etiological groups maintained essentially the same pattern for the three test frequencies is substantiated by the non-significant Frequency by Disorder interaction.

This difference in amount of shift between each of the test frequencies (500, 1000 and 4000 cps) indicates, as can be noted in Figs. 2, 3 and 4, that greater TTS is demonstrated as frequency increases.

By inspection of Figs. 2, 3 and 4 and taking the obtained standard deriva-

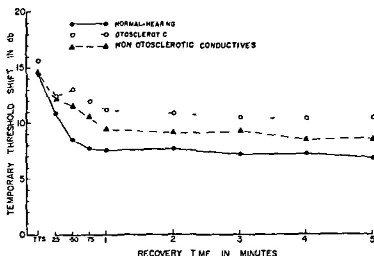


Fig. 3. Mean Temporary Threshold Shift for 1000 cps over recovery time for the Normal Hearing, Otosclerotic, and Non Otosclerotic Conductive Groups.

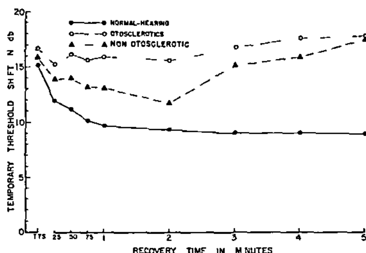


FIG 4 Mean Temporary Threshold Shift for 4000 cps over recovery time for the Normal Hearing Otosclerotic and Non Otosclerotic Conductive Groups

tions of the magnitude of 2–6 db into account it is obvious that the overlap which occurred for Initial Temporary Threshold Shift negates its use in clinically differentiating the Normals from the Otosclerotics or the Non Otosclerotic Conductives This is an example of a statistically significant difference which is not truly meaningful and supports the conclusions of Palva (17) and Epstein & Bower (8) who also felt that ITTS had little use in differential diagnosis

Temporary Threshold Shift over Time

A repeated measurements analysis of variance design was employed for evaluating Temporary Threshold Shift over time to consider the three test Frequencies at three Time intervals (0 5 1 and 5 minutes) for the three Disorder groups Bartlett s test of homogeneity of variance yielded a non significant chi square *Thus the assumption of homogeneity which is basic* to the analysis of variance is tenable The results of the analysis of variance are summarized in Table 3

These results suggest as has been noted in the literature (8 13 14 17) that the higher frequencies produce greater fatigue than do the lower frequencies These findings also point out that recovery differs significantly over time Not all frequencies showed similar threshold shift patterns over time From Figs 2 3 and 4 it can be seen that the subjects tended not to recover at 4000 cps whereas at 500 and 1000 cps it is evident that an on going progression toward pre exposure threshold over the five minutes occurred The interaction between Disorder and Time and Frequency may be disregarded because the major portion of the variance can be accounted for by the highly significant $T \times F$ interaction (P 0 001)

TABLE 3. *Analysis of variance, repeated measurements design for the Temporary Threshold Shift at 0.5, 1 and 5 minute points for the Normal, Otosclerotic, and Non Otosclerotic Conductive groups*

Source of variation	df	Mean square	F	Significance level
1 Disorder (*D*)	2	1168.88	9.86	.001
2 Time (*T*)	2	107.60	5.61	.01
3 Frequency (*F*)	2	1749.9[illegible]	36.69	.001
4[a] *S/D*	66	118.49		
5 *T* × *S/D*	132	19.17		
6 *F* × *S/D*	132	17.70		

[a] Line 4 was the error term for line 1, line 5 for line 2, line 6 for line 3. *S/D* is the within groups variance.

In order to determine the relation of the three groups to one another separate analyses of variance were employed. Table 4 summarizes the results of these analyses, namely between the Normals and Otosclerotics, the Normals and Non Otosclerotic Conductives, as well as the Otosclerotics and Non Otosclerotic Conductives for the three test Frequencies and the three Time intervals. These results, while indicating that the differences between the threshold shifts for the normal hearing group and the two conductively involved groups could not reasonably be attributed to chance, also reveal that the Otosclerotic and the Non Otosclerotic Conductive groups are not adequately differentiated. It can be seen from the graphic presentations of Temporary Threshold Shift over time (Figs. 2, 3 and 4) that the two pathological groups demonstrated greater fatigue than the normal hearing group. The pathological groups tended not to recover from the level of Initial Temporary Threshold Shift. This was particularly true at 4000 cps where the Otosclerotics and the Non Otosclerotic Conductives experienced further apparent fatigue by the third minute and continued in the direction of greater shift while the Normals showed a steady improvement following the ITTS. This is in agreement with Epstein and Bower's findings and serves to support their results at 1000 and 4000 cps for their Normal and Conductive groups. Thus it appears that 4000 cps offer the greatest potential in differentiating the normals from the conductives.

One might speculate that the surprising findings of Butler & Galloway (2) and Harford & Jerger (12) in which conductive hearing loss groups produced the highest error scores on the delayed speech feed back are related to the bizarre fatigue behavior noted by Epstein & Bower (8) and again in the present investigation. These findings might possibly be related to the "Hobble effect" noted by Fowler (9), that is, the recruitment like phenomenon that he observed in ears with conductive hearing loss compared with ears with normal hearing.

TABLE 4 *Analysis of variance, repeated measurements design between the Normal and Otosclerotic, and Normal and Non Otosclerotic Conductive, and the Otosclerotic and Non Otosclerotic Conductive groups at the 0 5, 1, and 5 minute points*

	Source of variation	df	Mean square	F	Significance level
			NORMAL AND OTOSCLEROTIC GROUP		
1	Disorder (*D*)	1	2263 34	19 83	001
2	Time (*T*)	2	76 53	4 29	05
3	Frequency (*F*)	2	969 06	22 22	001
4 [a]	*S/D*	44	114 12		
5	*T* × *S/D*	88	17 83		
6	*F* × *S/D*	88	46 35		
			NORMAL AND NON OTOSCLEROTIC GROUP		
1	Disorder (*D*)	1	977 05	8 70	01
2	Time (*T*)	2	88 18	5 10	01
3	Frequency (*F*)	2	938 29	23 12	001
4	*S/D*	44	112 32		
5	*T* × *S/D*	88	17 30		
6	*F* × *S/D*	88	40 58		
			OTOSCLEROTIC AND NON OTOSCLEROTIC GROUP		
1	Disorder (*D*)	1	266 24	2 06	NS
2	Time (*T*)	2	65 12	2 77	NS
3	Frequency (*F*)	2	1659 26	29 55	001
4	*S/D*	44	129 03		
5	*T* × *S/D*	88	23 53		
6	*F* × *S/D*	88	56 16		

[a] In each analysis line 4 was the error term for line 1 line 5 for line 2 line 6 for line 3 *S/D* is the within groups variance

Because of such puzzling implications concerning the nature of mechanical lesions of the auditory system and the possibility of uncovering information concerning the sensory neural mechanism it behooved us to seek the basis for the observed Temporary Threshold Shift over time The implications of the recruitment of loudness phenomenon derived from the measure of Variability Change will be discussed in a later section

Extent of Hearing Level (Loss)

A careful appraisal of the results for 4000 cps indicates that the Normal Hearing group had the best hearing and the least amount of temporary threshold shift The Miscellaneous group had the greatest hearing loss and demonstrated the most shift (26 db at the fifth minute) The group with intermediate degrees of hearing loss ordered themselves appropriately with respect to the fatigue measure (Serous 14 db Hyperplastic 16 db Otosclerotic 18 db)

TABLE 5. *Analysis of covariance for the Temporary Threshold Shift at the fifth minute and the pre-exposure Békésy threshold (uncontrolled variable) at 4000 cps for the Normal Hearing, Otosclerotic, Serous, Hyperplastic and Miscellaneous groups*

Source of variation	df	Mean square	F	Significance level
Disorder (D)	4	457.65	4.09	.01
S/D[a]	64	112.02		
Disorder (D)	4	59.68	.55	NS
S/D	63	109.37		

[a] In each analysis of variance the S/D, the within group variance, is the error term.

An analysis of covariance was applied to the relation between Temporary Threshold Shift and hearing level. It was hypothesized that the amount of threshold shift, when adjusted for the correlation between temporary threshold shift and the pre-exposure hearing level, would continue to be significantly different. Table 5 summarizes the analysis of covariance for 4000 cps at the fifth minute of recovery time for the five groups (Normal, Otosclerotic, Serous O. M., Hyperplastic O. M. and Miscellaneous). The results of the initial analysis of variance show that, prior to the adjustment of means for hearing level, the observed differences would occur only one in one hundred times by chance. Nevertheless, when the means are adjusted for the pre-exposure hearing level, the insignificant F value indicates that such differences can no longer be considered to differ from zero. One must assume that all subjects are drawn from a common population when the extent of their hearing loss is compensated for on a statistical basis. This procedure would draw the threshold shifts closer together. For example, the average shift for the Normal Hearing group was adjusted from 9.04 to 13.41 db, the shift for the Serous O. M. group remained almost unchanged (from 13.88 to 13.29 db). The Otosclerotic group's shift was reduced from 18.00 by about 2.5 db, the Hyperplastic O. M. group from 15.67 by about 1.5 db, and the Miscellaneous group from 26.50 by about 3.25 db.

An analysis of covariance was also computed at the one-half minute point in the recovery trace for 4000 cps. Table 6 summarizes this analysis. As was previously noted for the fifth minute in Table 5, the difference in temporary threshold shift at the one-half minute point was also considered highly significant in that such differences could be expected to arise once in one hundred times if only chance were operating. Following the adjustment of the means for the correlation between hearing level and Temporary Threshold Shift at one-half minute, such differences in threshold shift could no longer be shown to exist between Disorders. It appears likely that if such adjustments for pre-exposure hearing level are also made between the one-half and the fifth minute in the recovery trace, there will be essen-

TABLE 6 *Analysis of covariance for the Temporary Threshold Shift at the 0 5 minute point and the pre exposure Békésy threshold (uncontrolled variable) at 4000 cps for the Normal Hearing Otosclerotic Serous Hyperplastic and Miscellaneous groups*

Source of variation	df	Mean square	F	Significance level
Disorder (D)	4	73 59	4 46	01
S/D[a]	64	16 50		
Disorder (D)	4	22 40	1 36	NS
S/D	64	16 43		

[a] In each analysis of variance the S/D the within groups variance is the error term

tially no difference between the means for the disorder groups Initial threshold shift should behave in the same fashion when compensation is made for extent of hearing loss

It can be shown for the present sample at least that the greater the air conduction hearing loss the greater will be the temporary threshold shift This finding is remarkable in light of our present knowledge of conductive hearing loss and may be resolved on the basis of several explanations including that of Epstein and Bower s non linear block A further discussion of possible causes of the relationship between temporary threshold shift and hearing level is considered in Katz & Epstein (16)

Duration of Hearing Loss

Estimates of the duration of hearing loss were determined for each subject based on the individual s response to questioning concerning duration and onset of hearing loss and then converted into months (see Table 1) The Normal Hearing group which demonstrated the least amount of shift at the fifth minute of recovery time for 4000 cps had an average duration of less than zero months by definition the Serous group with the next least amount of shift averaged about 10 months of hearing loss The Hyperplastic group had a mean duration of 119 months while the Otosclerotic group s mean of estimated duration was 11 months The Miscellaneous group had the greatest shift and 175 months of hearing loss

Table 7 summarizes the analysis of covariance in which the estimated duration of hearing loss was controlled while the differences between means for 4000 cps at the fifth minute were considered The F value obtained prior to the removal of the duration factor was significant When the sums of squares were adjusted for the corrected means the obtained F value was no longer significant and suggested that the differences might well be attributed to chance

In order to determine whether the mean hearing level for each of the five

TABLE 7. *Analysis of covariance for the Temporary Threshold Shift at the fifth minute point and the estimated duration of hearing loss (uncontrolled variable) at 4000 cps for the Normal, Otosclerotic, Serous, Hyperplastic and Miscellaneous groups*

Source of variation	df	Mean square	F	Significance level
Disorder (*D*)	4	4[illegible]5.65	4.09	.01
S/D[a]	64	112.02		
Disorder (*D*)	4	159.38	1.44	NS
S/D	64	110.31		

[a] In each analysis of variance the *S/D*, the within group variance, is the error term.

groups would continue to be significantly different when duration was held constant, an analysis of covariance between these two variables was computed. Table 8 summarizes the statistical analysis. The resultant highly significant *F* values before and after adjustment indicates that the correlation between duration and hearing loss is not sufficiently great to spuriously produce significant results between the means. That is, real differences remain on the basis of hearing level regardless of the duration.

*It appears from these data and analyses that the unusual fatigue phe*nomenon which we have observed cannot be attributed to the presence of Otosclerosis exclusively, as Epstein and Bower postulated. Rather, our results suggest that Temporary Threshold Shift possibly reflects a condition common to all conductive hearing losses relative to the extent and duration of the loss.

Prediction of Temporary Threshold Shift

Because of the demonstrated relationship of both hearing level and duration of loss to Temporary Threshold Shift, product moment correlations and a multiple correlation were computed to determine if hearing level and duration were measuring primarily common variance. That is, were duration and hearing loss reflecting the same factor or did each contribute some unique information? The Pearson product moment correlation between the Temporary *Threshold Shift at the fifth minute following the low level exposure* and hearing level on the Bekesy type audiometer was 0.44, indicating that 80 per cent of the variance was not predicable on the basis of extent of hearing loss. When the Temporary Threshold Shift was compared with duration of hearing loss, an *r* of 0.38 was obtained. Duration was therefore a slightly poorer predictor of Temporary Threshold Shift because it left 8o per cent of the variance unaccountable. The correlation of 0.63 between duration and *hearing level indicates that as the duration of the loss increases the more* likely it is that the loss will be greater. This would logically be the case in patients with otosclerosis but not necessarily in conditions such as radical

TABLE 8 *Analysis of covariance for the hearing level and the estimated duration of hearing loss at 4000 cps for the Normal Otosclerotic Serous Hyperplastic and Miscellaneous groups*

Source of variation	df	Mean square	F	Significance level
Disorder (D)	4	7029 07	42 74	001
S/D[a]	64	164 47		
Disorder (D)	4	3344 14	21 17	001
S/D	64	157 95		

[a] In each analysis of variance the S/D the within groups variance is the error term

mastoidectomy Because 61 per cent of the variance remains to be resolved it seemed worthwhile to treat hearing loss and duration separately Each of the above correlations was found to be statistically significant

The multiple correlation for Temporary Threshold Shift with hearing level and duration of loss taken together is 0 46 (also significant) which indicates that 21 per cent of the variance is associated with or predicted by the combination of hearing level and duration However when R is corrected for sample size it is reduced to less than 0 44 We are therefore equally accurate when employing both duration and extent of loss as when we use extent of loss alone

Should we care to predict the Temporary Threshold Shift at the fifth minute at 4000 cps for any of our subjects we can apply the prediction formula given by Guilford (10)

$$X = r\frac{\sigma_x}{\sigma_y}(Y - M_y) + M_x$$

where X is the Temporary Threshold Shift to be predicted r is the correlation between the two variables (0 4426) σ_x and σ_y are the standard deviations for Temporary Threshold Shift (11 42 db) and hearing level (23 66 db) respectively Y is the hearing level for the subject in question M_y is the mean hearing level for all subjects (23 62 db) and M_x is the mean Temporary Threshold Shift (13 81) Thus

$$X = 0\ 214(Y - 23\ 62) + 13\ 81$$

The resultant standard error of estimate corrected for the bias introduced by the small sample was 5 25 db We can therefore suggest that only 2 5 in 100 times would subjects such as ours exhibit less shift than 10 5 db below the predicted scores For example a subject with a conductive loss of 40 db at 4000 cps would be expected to exhibit 7 db or more shift after 5 minutes of recovery time That is we would predict a score of about 17 db and when we subtract two times the standard error of estimate we obtain a lower limit

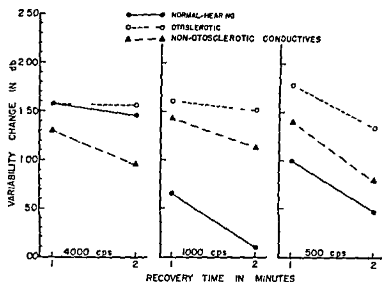


Fig 5 Mean Variability Change at 500 1000, and 4000 cps for the first and second minute of recovery time for the Normal Hearing Otosclerotic, and Non Otosclerotic Conductive Groups

of 7 db Although there is insufficient evidence to suggest that this test may be used clinically in its present form, we would expect, on the basis of Epstein & Bower's findings, that such a tool would successfully differentiate conductives from sensory-neurals, even for clinical purposes, if such criteria were employed It remains for replication of the present data on conductives and normals and further clinical experimentation to provide the upper fiducial limits for sensory-neural hearing losses This might possibly lead to even greater certainty in clinical diagnosis

Variability Change

The change in the amplitude of the Bekesy envelope appeared to be a somewhat unstable measure which was evidenced by the large standard deviations within each group Nevertheless, it is of interest to note from Fig 5 that the Normal Hearing Otosclerotic and Non Otosclerotic Conductive groups all tended to widen their excursions from the first to the second minute for 500 cps Narrowed amplitude of the Bekesy envelope has been considered evidence of the presence of the recruitment loudness phenomenon (1 18) There is clinical experimental evidence to show that recruitment of loudness is associated with end organ fatigue or trauma (3, 4 11, 15) rather than nerve fiber involvement It may be inferred that the three groups tended to recover at a fairly rapid rate at 500 cps during the first to the second minute The amount of recovery (widening of excursion toward that of the pre exposure trace) appeared to be similar for each group in spite of either the amplitude of the envelope before exposure or at the first minute

At 1000 cps the Variability Change from the first to the second minute

appears to recover less for the conductive groups than for the normals. The Normal group exhibited essentially the same tendency toward pre-exposure variability about threshold as they did at 500 cps. The Otosclerotic group and Non-Otosclerotic Conductives remained in a similar state of recruitment between the first and second minutes while the normals regained their pre-exposure amplitude by the second minute. This may be taken as support not only for our Temporary Threshold Shift measure but also for a more persistent disturbance in the cochlea for conductive groups which is not evidenced in the Normal Hearing group.

At 4000 cps the Normal Hearing group was also resistant to recovery. At this test frequency the three disorder groups recovered minimally from the first to the second minute and maintained about 1.5 db of Variability Change.

Because of the spread in means at 1000 cps, an analysis of variance technique was computed to test the significance between them. An F value of 3.86 was obtained which was significant at the 5 per cent level. The behavior noted at 4000 cps for the normal hearing subjects on the Variability Change measure did not follow the expected pattern based on their performance at 500 and 1000 cps. An adequate explanation for this finding cannot be offered.

ZUSAMMENFASSUNG

Ein 20 db SL Ton wurde mit 4000, 1000 und 500 Hz je drei Minuten lang gegeben. Nach jeder Exponierung zeichneten die Versuchspersonen ihre Schwellen zu dem Reizton fünf Minuten lang auf einem automatischen Audiometer vom Typ Békésy nach. Sechsundvierzig Versuchspersonen mit leitungsgestörtem Gehör und dreiundzwanzig Versuchspersonen mit normalem Gehör wurden geprüft.

Auf Grund dieser Versuchsreihe werden folgende Schlussätze als haltbar betrachtet:

1. Epstein und Bowers Ergebnisse, die eine grössere zeitweilige Schwellenverschiebung (Temporary Threshold Shift = TTS) über einen gewissen Zeitraum für leitungsgestörte Ohren als für normale Ohren andeuten, wurden bekräftigt.

2. Viertausend Hz verursachten die grösste TTS und boten die deutlichste Unterscheidungsmöglichkeit zwischen normalen und gestörten Gehören, besonders unter der fünften Wiederherstellungsminute.

3. Das Ausmass der TTS stand in positivem Zusammenhang sowohl mit dem Grad des Hörverlustes als auch mit der Dauer desselben ohne Rücksicht auf die spezifische Ätiologie.

4. Obwohl sich normale und leitungsgestörte Gehöre hinsichtlich der anfänglichen zeitweiligen Schwellenverschiebung unterschieden, erweist sich hierbei eine gewisse Ungewissheit für die klinische Diagnose auf Grund einer beträchtlichen Überlappung zwischen den beiden Gruppen.

5. Die Verwendung von TTS für klinische audiometrische Feststellung von Gehörverlust auf Grund von Leitungsstörung erscheint möglich.

6. Die Prüfung des Veränderlichkeitswechsels gab weniger eindeutige Ergebnisse als TTS bei der Unterscheidung leitungsgestörter von normalhörenden Versuchspersonen.

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THE INFLUENCE OF HYPNOTIC SUGGESTION ON VESTIBULAR NYSTAGMUS

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Subjects susceptible to hypnosis who could also be classified as vestibular normals, were selected for the investigation. After a preliminary hypnotic training they were subjected to rotatory and caloric stimulation using test conditions as close as possible to those used in oto-neurological examinations. The nystagmus induced was recorded behind closed eyelids.

Nystagmic responses to vestibular stimuli of similar intensity were measured in five successive tests (1) control without hypnosis (2) hypnosis alone (3) hypnosis and suggestion of decreased rotatory sensation (4) hypnosis and suggestion of increased rotatory sensation and (5) control without hypnosis.

The results showed that in most of the subjects the intensity of the induced nystagmus was lowest under test 3 and highest under test 4. Thus it was usually possible to change the intensity in a desired direction by means of hypnosis and verbal suggestion.

In the rotatory tests it was possible to influence both the eye speed and the duration of the nystagmus. In the caloric tests only the eye speed changed. These differences might be explained by the differences in principle in stimulating both labyrinths during rotation but only one when performing the caloric test.

Special attention is directed to slow pendular eye movements which can be induced by hypnosis alone. Vestibular stimuli tend to interrupt this kind of eye movements, an effect which is interpreted as an arousal response.

Habituation or response decline was to some extent present in the rotatory tests but the experimental arrangements made it possible to show that hypnosis and verbal suggestion was the main reason for the changes in nystagmus intensity observed.

The clinical and theoretical implications of the findings are discussed.

During the last decades nystagmography has been accepted as a routine method in clinical oto-neurological examination. The main reason is that with this technique it is possible to record the eye movements under different visual conditions and to avoid the inhibitory effect of fixation on vestibular nystagmus. Moreover nystagmography makes it possible to assess not only the duration of vestibular induced nystagmus but also other parameters such as the eye speed in the slow phase of nystagmus, number of beats, etc. as a measure of the intensity of the nystagmus. This has brought up a lively

discussion concerning the normal limits of variation of in particular the eye speed in the slow nystagmus phase which has attracted the greatest clinical interest since *it may yield an adequate index of the degree of symmetry* in the vestibular tonus (Cawthorne *et al.* 1942, Aschan *et al.* 1956, Henriksson 1956, Stahle 1958).

Pronounced asymmetries which seem to have no pathological basis have been reported among "normal" subjects. This can depend on our still rather incomplete knowledge about the factors which, apart from labyrinthine stimuli, can normally influence the intensity of nystagmus. There is evidence that the ability to suppress vestibular nystagmus by fixation can be increased by training and thus partly account for such phenomena as compensation after unilateral labyrinthectomy (Aschan 1956, Aschan *et al.* 1956) and suppression of rotatory nystagmus in persons accustomed to intense rotations (McCabe 1960). Habituation to repeated vestibular stimuli as well as response variations corresponding to changes in the subject's awareness or mental state may, however, also occur when fixation is avoided, a fact indicating that higher levels of the nervous system are also involved in a more direct control of the vestibulo-ocular reflexes (Hallpike & Hood 1953, Hood & Pfaltz 1954, Lidvall 1961, Mahoney *et al.* 1957, Collins *et al.* 1961).

Wendt (1936) used rotation as the unconditioned stimulus in an attempt to establish conditioned nystagmus to auditory stimuli but the results were negative since he did not succeed in conditioning the slow phase. Dorcus (1937) tried to elicit nystagmus by hypnotic suggestion but stated that "the eye movements under hypnosis were of a voluntary type and were unlike the true nystagmic movements following rotatory stimuli". On the other hand *Platonow (1930) maintained that with hypnosis he could modify* vestibular nystagmus and Medvedevsky & Nevsky (1940) stated that "real" nystagmus can be induced by suggestion.

The aim of this investigation was to find out if the nystagmus resulting from rotatory or caloric vestibular stimulation can be influenced by hypnotic suggestion. We tried to use vestibular stimuli and a procedure similar to that used in clinical oto-neurological routine since only under such conditions can positive results have any practical clinical value. Eye movements were always recorded behind closed eyelids in order to exclude visual influence on the vestibular nystagmus.

METHODS

The subjects for the investigation were selected so that from their previous histories etc. they could be classified as vestibular "normals". They were also selected in the sense that they were all known to be good hypnotic subjects. The experimental design and the purpose of this investigation was however unknown to them. Ten subjects were used for the rotatory experiment. Four of them participated in two experiments with an interval of some weeks, the rest took part in only one experiment. Seven subjects were used for the caloric experiments on one occasion only. Some of the subjects took part in both the rotatory and caloric experiments.

Hypnosis and suggestion

The subjects had a preliminary training when they lay comfortably on a couch and were taught to keep their body muscles relaxed by alternate contraction and relaxation of each major muscle group. The gaze was then directed upwards and backwards and fixed on a point on the ceiling while verbal suggestions of increasing relaxation and sleepiness were repeated monotonously in time with the respiration. When the eyes had closed, tests were made for increased suggestibility, e.g. inability to loosen the clasped hands, absence of withdrawal to pinprick and loss of the plantar response following suggestions of anaesthesia of the sole of the foot. The last of these tests has not previously been described but one of us (B. L. F.) has found it to be a useful sign of increased suggestibility during hypnosis. Positive tests were accepted as indicating the presence of the hypnotic state.

After this preliminary training it was usually easy to induce hypnosis again, even in the sitting position required for the rotation tests. The specific suggestions repeated monotonously during the rotatory and caloric stimulations maintained that the stimulus was either weak or strong and that the sensations of turning was accordingly completely insignificant or very intense.

Nystagmography

Nystagmography was performed during all the tests using the method described by Aschan (1955 b) and in more detail by Aschan *et al.* (1956) using an AC amplification system with a time constant of 3 seconds. All records refer to horizontal leads and horizontal eye movements with the electrodes at the outer canthi of the eyes. Calibration was performed for 10° eye movements by alternate fixation of two points 3.5 meters away from the subject's eyes.

The rotatory stimulus

The rotary stimulus was applied in the rotating chamber described by Aschan *et al.* (1953). The turning of this chamber is regulated by an electronic control unit providing constant acceleration and deceleration, as well as a constant speed between these phases to a high degree of accuracy. Fig. 1 shows how the movements of the chamber can be followed in the various phases of rotation by oscilloscope recording of the electrical output from a generator coupled to the rotating axis of the chamber. In these experiments this control is essential to make sure that exactly the same stimulus is applied during the different rotation tests. The closed rotating chamber also excludes other sources of error, e.g. optokinetic stimulation, draughts on the subject's body etc., which occur when a conventional open rotating chair is used.

The subjects were rotated sitting with the head tilted forward 30°, as in the clinical A D test (Acceleration Deceleration test). After acceleration 6°/sec² for 10 seconds the constant speed of 60°/sec was maintained for 150–180 seconds so that all perrotatory nystagmus and possible secondary nystagmus had disappeared before deceleration of 6°/sec² began. Thus each separate turning test induced nystagmus in both directions.

Rotations were alternately to the right and left to avoid as much as possible a response decline (habituation), which according to Mowrer (1931) and Hallpike &

Hood (1953) shows directional specificity (cf also Stahle, 1958) Each subject was rotated according to the following plan

1 Rotation to the right, without hypnosis or suggestion
2 Rotation to the left, under hypnosis but without specific suggestion
3 Rotation to the right, under hypnosis and suggestion of reduced sensation of rotation
4 Rotation to the left, under hypnosis and suggestion of increased sensation of rotation
5 Rotation to the right as under test 1, without hypnosis and suggestion

Rotations 1 and 5 were used as controls and they also allowed a check as to whether a response decline was present or not Rotations 2–4 were carried out without arousing the subject from the hypnotic state There was a pause between each rotation of at least 3 minutes and during these pauses the subject was again told to relax and to raise his arm in the air as a signal of when he felt as comfortable as before

The calorizations

The calorizations were carried out with the patient in the same position as used in clinical examinations, lying supine with the head tilted forward 30–40° The water was taken from a constant temperature water bath In the rotation experiments each turning test induced both right and left beating nystagmus, but in the calorization experiments two successive syringings had to be performed in each test to induce nystagmus of both beating directions This meant either syringing first one and then the other ear with, for example, cold water or the same ear first with cold and later with warm water Four of our subjects were tested with the binaural and three with the mono aural method To avoid habituation following repeated stimulation we systematically alternated the direction of beating of the induced nystagmus There was always a pause of about 10 minutes between each syringing not including the time for the nystagmus period This made a complete calorization experiment far more time consuming than a complete rotation experiment

Every subject was tested according to the following scheme

1 Two syringings producing right as well as left beating nystagmus, without hypnosis or suggestion
2 Two syringings as before but under hypnosis without suggestion
3 Two syringings as before under hypnosis and with suggestion that the subject would feel no sensation of turning
4 Two syringings under hypnosis and with the suggestion that he would feel a severe sensation of turning
5 A last check identical with test 1

RESULTS

Rotation experiments

In 11 out of 14 rotation experiments the hypnotic suggestions influenced the intensity of the induced nystagmus in a systematic way Thus the lowest intensity of nystagmus was recorded during hypnotic suggestion of decreased sensation of rotation (test 3) while the highest intensity appeared during

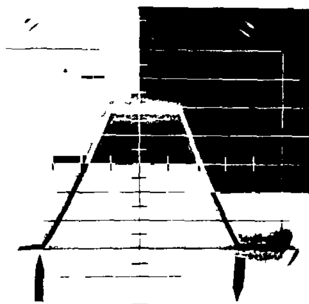


Fig. 1. Oscilloscopic control of the turning of the rotating chamber showing the linearity of acceleration, constant speed and deceleration.

suggestion of increased sensation of turning (test 4). In the three "negative" experiments the suggestions had no measurable effect.

A single representative experiment is shown in Fig. 2, which contains five pairs of nystagmus records, the numbers 1–5 referring to the five different rotations as described above under methods. In each pair of curves the records are grouped so that the upper curve always shows right beating, the lower left beating nystagmus. The calibrations for 10° eye movements at the beginning and the end of the experiment (to the left in the figure) are identical and the curves can thus be compared directly. Two parameters were used as a quantitative measure of the nystagmic responses: the duration of induced nystagmus and the eye speed in the slow phase of nystagmus. Both the maximum eye speed during the ten seconds of acceleration and deceleration and the maximum after the end of acceleration-deceleration were calculated from the records. It is easily seen in the figure that the lowest intensity is in rotation test marked 3 and the highest in rotation test marked 4. The calculated figures from the records shown in Fig. 2 are assembled in Table 1.

It should be noted that besides the effect induced by the hypnotic suggestions (3 and 4 compared with 1 and 5) it seems as if the hypnosis per se caused a decrease in the nystagmus intensity (2 compared with 1 and 5). This was a common finding in these rotation experiments.

In the large majority of experiments it was also observed that the response to rotation 5 was less intense than the initial control rotation, indicating that a slight response decline (habituation) tended to occur.

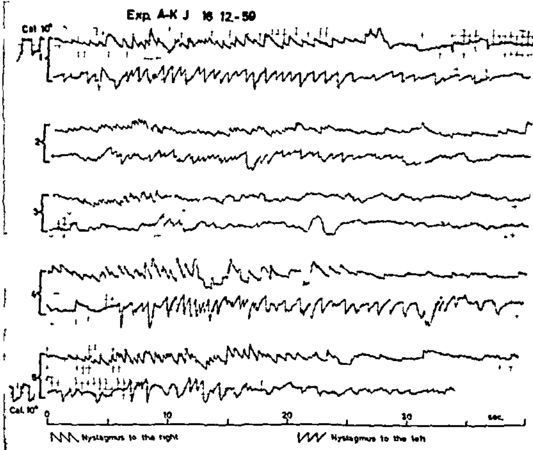


Fig. 2. All records from a complete rotatory experiment. Numbers 1–5 refer to the five different tests of the experiment: (1) control without hypnosis, (2) hypnosis alone, (3) hypnosis and suggestion of decreased sensation, (4) hypnosis and suggestion of increased sensation, (5) control without hypnosis. N.B. The lowest intensity is seen in record 3, the highest in record 4.

As shown by the records in Fig. 2 it is sometimes almost impossible to measure the exact duration of the nystagmus (see rotation 3), whereas the eye speed in the slow phase of nystagmus can usually be measured quite accurately. This is one of the reasons why the latter parameter is a more reliable index of the state of excitability in the vestibulo-ocular reflex arc.

TABLE 1

Acceleration			Deceleration		
Duration	(sec)	Eye speed	Duration	(sec)	Eye speed
1 r beating	30	20-16°/sec	l beating	40	22-20°/sec
2 l beating	30	11-10°/sec	r beating	25	8-6°/sec
3 r beating	10	4-0°/sec	l beating	0?	0-4°/sec
4 l beating	45	32-34°/sec	r beating	40	26-25°/sec
5 r beating	30	15-15°/sec	l beating	25	12-12°/sec

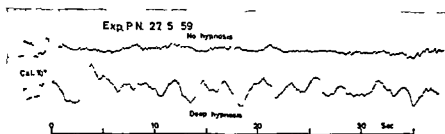


Fig. 3. The appearance of slow pendular eye movements in deep hypnosis. See text.

Usually the duration and eye speed indices varied in parallel during the course of our experiments but sometimes one of the parameters reflected the variations more clearly than the other.

In six of those subjects in whom suggestions had an effect on the intensity of the nystagmus an additional and rather unexpected observation was made. This is illustrated in Fig. 3 where the upper curve shows a typical nystagmogram behind closed eyelids with the subject fully awake and without vestibular stimulation. When the subject was hypnotised, however, there appeared slow pendular eye movements resulting in high amplitude, fairly regular potential fluctuations (lower record).

Fig. 4 is derived from a second experiment on the same subject. The initial part of the record shows the same pendular eye movements under hypnosis. When suddenly the 6°/sec² acceleration starts the pendular movements immediately disappear and the perrotatory nystagmus is recorded. At the arrow marked "end acceleration" the subject is turning at a constant speed of 60°/sec and as now the perrotatory nystagmus gradually disappears the pendular eye movements return. None of the subjects showed these pendular movements in the normal waking state.

The calorization experiments

The calorization experiments also showed that hypnotic suggestions influenced the intensity of the induced nystagmus in a systematic way. Only

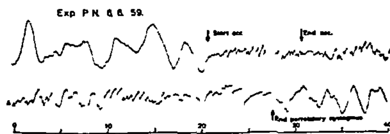


Fig. 4. The blocking effect of rotatory stimulation on the slow pendular eye movements which reappear when the induced perrotatory nystagmus gradually dies away.

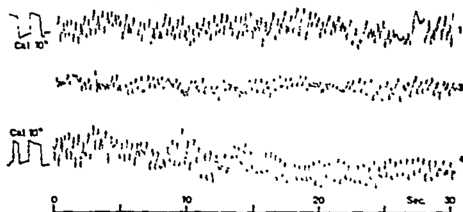


Fig. 5. Caloric induced nystagmus 60–90 seconds after starting the irrigation. (1) control without hypnosis, (3) hypnosis and suggestion of decreased sensation, (4) hypnosis and suggestion of increased sensation. N.B. The lowest intensity is seen in record 3, the highest in record 4.

seven such experiments were carried out and they all gave similar results. Only variations in the eye speed were noticed, the duration was generally not affected. The third pair of calorizations under "hypnosis plus suggestion of decreased sensation" showed the lowest intensity of the nystagmus induced. The fourth pair of calorizations under "hypnosis plus suggestion of increased sensation of turning" always showed the highest intensity of the nystagmus.

Besides the fact that the duration of the caloric induced nystagmus was not affected in the same way as in the rotation experiments, there was also another difference between the two series in that hypnosis alone gave no changes in the intensity of caloric induced nystagmus.

Three typical records are shown in Fig. 5. They all correspond to the period 60–90 seconds after the beginning of the irrigation and they all show left beating nystagmus. The upper curve is the control marked 1 in the scheme given under methods. The middle curve represents "hypnosis plus suggestion of decreased sensation" (3). The lowest curve corresponds to calorization number four "hypnosis plus suggestion of increased sensation". The decrease of the intensity in the middle curve is particularly easy to see in the records. The conventional way of illustrating the intensity of caloric induced nystagmus is to give the maximum eye speed. In the experiment illustrated in Fig. 5 the values were the following (for 10 sec periods 60–90 sec after starting the irrigation): for the calorizations under tests 1, 2 and 5 maximum eye-speeds ranging between 32–36°/sec mean 32.5°/second, for the calorizations under tests 3 and 4 corresponding mean values of respectively 16°/sec and 43°/sec. However, in all these calorizations the duration was almost the same, about 2 minutes and 30 seconds. Graphically the experiment can be compressed into a simple diagram as in Fig. 6 where the middle curve represents the control tests, the lowest curve the calorizations with hypnosis and suggestion

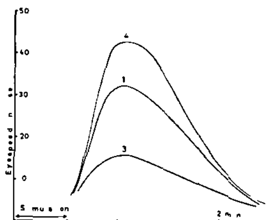


Fig 6 Graphical demonstration of the three syringing tests shown in Fig 5 The eye speed in the slow phase of nystagmus (ordinate) is plotted against time (abscissa) (1) control without hypnosis (3) hypnosis and suggestion of decreased sensation (4) hypnosis and suggestion of increased sensation

of decreased sensation and the upper curve the calorizations under hypnosis with suggestion of increased sensation

Fig 5 and the diagram in Fig 6 are representative of all the other caloric experiments

DISCUSSION

The experiments have shown that hypnotic suggestion of decreased or increased rotatory sensation can elicit systematic variations in the intensity of the nystagmic responses following both rotatory and caloric stimuli However the experiments involved repeated stimuli and the first point to be discussed is to what extent the repetition in itself can influence the results

Repeated angular acceleration (rotation) is known to result in a reduction of the nystagmic response Hallpike & Hood (1953) called this a response decline but the term habituation is also frequently used in order to emphasize that the phenomenon is probably due to central neural events rather than peripheral sensory changes Mowrer (1934) and Hood & Pfaltz (1954) studied the response decline in animals and Griffith (1920) Dodge (1923) Holsopple (1924) Groen & Jongkees (1948) Aschan Nylen Stahle & Wersäll (1952) and Stahle (1958) analyzed various aspects of the phenomenon in man The conclusions from the clinical rotation tests were that strong acceleration produced a more marked response decline and thus weak acceleration was recommended in methods known as cupulometry or acceleration/deceleration test (A D test) The reason why we chose the A D test was that this method involves only one rotation to produce nystagmus beating in both directions

In our rotatory experiments there was often a response decline as shown

by the fact that rotation 5 gave a weaker response than *rotation 1 (Fig. 2, Table 1)*. This change of the control value was small, however, compared with the changes accompanying the hypnotic suggestions. The response to rotation 3 (suggestion of decreased sensation) was smaller than the weakest of the controls and the response to rotation 4 (suggestion of increased sensation) exceeded the maximal control value. Furthermore, the suggestions of increased sensation were purposely given at the end of the hypnotic session so that a response decline occurring between rotations 3 and 4 would counteract rather than add to the effect of the suggestions.

Using the temperatures +30°C and +44°C as cold and warm stimuli in *the caloric test and always applying the caloric stimuli so that the caloric* induced nystagmus beat in alternate directions, Hood & Pfaltz (1954) could not find a response decline following repeated caloric stimulation when measuring the duration of the caloric nystagmus only. This has been confirmed by Mittermaier (1950, 1955), Aschan *et al.* (1956), Henriksson (1956) and Stahle (1958). The latter authors used nystagmography and were thus able to refer the intensity not only to the duration but also to other parameters such as total amplitude, number of beats and eye speed in the slow phase of nystagmus. They all found great random variations especially in the eye speed. Statistical analysis of larger series, however, does not give evidence of a response decline during *repeated caloric stimulation following* the usual clinical routine for testing (Aschan, Bergstedt & Stahle 1956, Stahle, 1958). It must be pointed out, however, that under extreme experimental conditions such as repeated calorization of one ear in the same way a response decline might also appear following caloric stimulation (Lidvall 1961).

In our present calorization experiments there was also no evidence of response decline, but in most subjects the intensity of the nystagmus as measured by the eye speed showed systematic variations corresponding to the verbal content of the hypnotic suggestions.

It should be noted that in most of the rotatory experiments the duration of the nystagmic response as well as the eye speed showed marked changes whereas in the caloric experiments only the eye speed was affected by the suggestions (Fig. 6). The reason for this discrepancy is unknown but it must be emphasized that there is a fundamental difference between the stimuli employed in the two kinds of experiments. The rotatory stimulus is physiological in the sense that it involves both labyrinths and the rotatory induced nystagmus is almost always combined with a turning sensation which is correlated to some extent with the intensity of the nystagmic response. The caloric stimulus, on the other hand, involves only one labyrinth and with the *stimulus strengths used in the present study the subjective rotatory sensations* may be very weak or even absent, despite the fact that the nystagmus response is strong. It may be postulated that if both ears are irrigated, cold on one side and warm on the other, peripheral cupular deviations similar to those in the rotatory test appear and in this case the nystagmus is always

accompanied by a very marked sensation of turning and nausea (Aschan 1955a) These differences between rotatory and mono aural caloric stimulation are emphasized because they may be relevant when trying to explain the discrepancy between the rotatory and caloric results in our present study

There is evidence that during hypnosis the working of the vascular system is more like that in consciousness than that of sleep (Crasilneck & Hall 1960) and also the EEG is generally more like that of wakefulness than that of sleep (Diamant *et al* 1960) In view of these facts it is of interest to note that during hypnosis we often recorded slow pendular eye movements which according to several authors are typical of stages of light sleep or coma (Miles 1929 Alfandary 1937 Aresinsky & Kleitman 1955) This seems to support the idea that even though there are great differences between hypnosis and ordinary sleep some of the neural mechanisms behind the two conditions may be similar Wendt (1936) who observed pendular eye movements in *animals immobilized under animal hypnosis describes them as characteristic* of a state of lowered wakefulness in which the nystagmic responses to vestibular stimuli are usually suppressed

In this laboratory the slow oscillatory eye movements have earlier been observed most clearly in patients with slow cerebration due to brain tumors in subjects on promethazine chloride medication and in subjects experimentally intoxicated by alcohol Promethazine chloride alone and in combination with alcohol induced the phenomenon quite regularly alcohol alone only when the intoxication was such that the subject was asleep *If he was* aroused the pendular movements vanished and a previously concealed positional alcohol nystagmus appeared (Aschan to be published) In the experiment illustrated by Fig 4 the acceleration not only induces nystagmus but it apparently also serves as an arousal stimulus which temporarily blocks the pendular movements During the post acceleratory period the two patterns of eye movements seem to appear in alternate runs in an almost reciprocal fashion (cf Wendt 1936) Mahoney *et al* (1957) and Lidvall (1961) showed that *discontinuity (dysrhythmia) in caloric nystagmus can be prevented by* letting the patient solve an arithmetical problem indicating that the silent periods in a discontinuous nystagmus may correspond to periods of lowered wakefulness They do not mention however whether in their experiments slow pendular movements tended to occur during these periods

From the clinical point of view it is of interest that hypnotic verbal suggestions can have such a marked influence on the nystagmic responses following both rotatory and caloric stimuli Our vestibular testing procedure was similar to that used *in clinical practice* and we think that providing the subjects are highly suggestible changes similar to those observed in the present study may also occur in clinical routine examinations The fact that these changes are most marked in the rotatory test fits in well with clinical experience that the rotatory tests are those which show the greatest random variations As pointed out by Stahle (1958) there is now a tendency to avoid rotatory tests in clinical practice and the present results give still more reason to

by the fact that rotation 5 gave a weaker response than rotation 1 (Fig. 2, Table 1). This change of the control value was small, however, compared with the changes accompanying the hypnotic suggestions. The response to rotation 3 (suggestion of decreased sensation) was smaller than the weakest of the controls and the response to rotation 4 (suggestion of increased sensation) exceeded the maximal control value. Furthermore, the suggestions of increased sensation were purposely given at the end of the hypnotic session so that a response decline occurring between rotations 3 and 4 would counteract rather than add to the effect of the suggestions.

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EOSINOPHILIC GRANULOMA IN THE ORAL CAVITY

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A survey of the inclusion of the eosinophilic granuloma among the reticuloses is given with a short description of the histology, signs and symptoms and a review of the most important otological and dental literature A case of eosinophilic granuloma in the oral cavity treated with radiotherapy and corticotropine with a recurrence free period of 4 years is reported The problems of treatment are discussed

The eosinophilic granuloma belongs to the reticulosis—a group of diseases characterized by a non lipoid storage disorder of the reticulo endothelial system—and is therefore related to Hand Schuller Christian s disease and Letterer Siwe s disease

Clinically these three diseases differ but there is no clear distinction between them Transitional forms are found and each disease can develop into another within the group (Mallory 1942 Hoxie 1955 Bach 1957)

Eosinophilic granuloma was first described by Jaffe and Lichtenstein in 1944 The disease is usually found in children and young adults (Schuknecht & Pearlman 1948) and characterized by localized changes in one or more bones (Dingley 1952) It is comparatively benign and may heal spontaneously (Jaffe & Lichtenstein 1944 Wilson & Sommerfeld 1959) In a few cases it may be an initial form of the Hand Schuller Christian s disease (Dawes 1954 Bach 1957)

Literature

Several cases of eosinophilic granuloma have been reported in otological literature since Schuknecht and Pearlman s publication in 1948 These mainly concerned cases localized to the mastoid temporal bone either in one or both sides (Dingley 1952 Dawes 1954 Hoxie 1955 Wilson & Sommerfeld 1959) In two cases only lesions of the mandible were also described (Albano *et al* 1956 Hoxie 1955)

More cases of eosinophilic granuloma of the jaws have been described in dental literature (Brasshaw & Orban 1953 Thoma 1945) The subject has been discussed in most detail in the work of Thoma in 1945 It is apparent that lesions in other bones are often present In two cases only has the lesion been restricted to the mandible

Pathology

Histologically the lesions of the involved organs are practically identical in the three diseases

There is a granuloma like tissue mainly consisting of hyperplastic histiocytes in a sheet like arrangement The histiocytes are of a light finely or coarsely granular cytoplasma and often of a foam cell like appearance This area is infiltrated by a large number of eosinophiles Secondary inflammation is represented by lympho and leucocyte infiltration Multinuclear giant cells may also be present (Mallory 1942 Brayshaw & Orban 1953 Dawes 1954 Hoxie 1955 Albano *et al* 1956)

Some differences between the diseases may be demonstrated in the histological picture The hyperplastic histiocytes dominate in the Letterer Siwe s disease and the eosinophiles in the eosinophilic granuloma Marked foam cells (xanthom cells) mean lipoid (cholesterol) storage and are seen in the late phases of a chronic course as in Hand Schuller Christian s disease (Jaffe & Lichtenstein 1944 Orrild & Lunding 1953)

Signs and Symptoms

The signs and symptoms of the eosinophilic granuloma are relatively vague and often the disease is diagnosed through a pathological fracture of an involved bone In spite of the extensive local lesions the general state of the patient is surprisingly good and pain is rare (Dawes 1954) In cases with changes lying superficially as in the face and skull a soft fluctuant swelling with ill defined borders may be felt

When the disease is localized to the mastoid temporal bone the most common sign is discharge from the ear which shows no response to treatment Granuloma in the external auditory meatus may be found and in the postauricular region there may be swelling and ulceration (Dingley 1952 Dawes 1954 Hoxie 1955) The hearing may be damaged but this is a relatively late manifestation A few cases of facial paralyses have also been reported (Dingley 1952 Dawes 1954)

If located in the oral cavity the gingivae and the alveolar processes are usually the seat of the disease and are then thickened The mucuous membranes are ulcerated and granular and the teeth are loose with naked collums or necks in the areas involved (Brayshaw & Orban 1953 Thoma 1945)

The radiological picture may show a punched out lesion with no osseous reaction in the surrounding tissue The changes are most often found in the flat bones and in the ribs but may present a honeycomb like picture in the epiphyses of the long bones (Dawes 1954)

In the temporal bone the squama is first attacked and the petrosal part may be seen as an isolated bone in the surrounding clear area The process usually stops in a relatively clear cut fashion short of the bony labyrinth and this may explain the late effect on the hearing (Dingley 1954)

The lesions in the jaws may show a cyst like picture with the teeth lying free in these areas (Brayshaw & Orban 1953 Hoxie, 1955)

The blood picture is essentially of no value in the diagnosis An eosino philia of 4–10% may be present The blood cholesterole is usually within normal limits (Hoxie 1955)

Biopsy with demonstration of the pathological characteristics is conclusive for diagnosis It is of vital importance to get adequate specimen to be certain of finding all the characteristic features of the disease (Dawes 1954)

Treatment

Most of the authors recommend radical surgical removal in connection with radiotherapy as the method of choice but radiotherapy itself may also result in healing Dingley in 1952 proposed the use of ACTH as a treatment based on the influence of this stuff on the eosinophiles and in 1955 Hoxie suggested that radioactive isotopes could be of some importance

In 1953 Orrild and Lunding reported a case of Letterer Siwe s disease treated with corticotropine in which complete healing occurred Roejel too has treated a case of Letterer Siwe s disease with corticotropine and strepto mycine This however had a fatal outcome

The theory of these experiments is based partly upon the thesis of Asboe Hansen in 1950 in which it was demonstrated that ACTH reduces the number of plasma cells and partly on the publication of Teilum the same year where a decrease of the hyperplasia of plasma cells in hyperimmunized rats was shown

Case Report

The following case of eosinophilic granuloma is considered of interest because of its unusual localization and because corticotropine treatment was instituted

In 1956 a boy aged 3 years was admitted to the hospital He had previously been healthy with exception of a non complicated right sided otitis media at the age of 3 months There was no familial disposition to blood diseases or cancer

For 9 months before admission he had suffered from a discharge from the left ear This had been treated with penicillin and syringing without effect Two months before admission he had a granuloma removed from the external ear canal Histologically this showed resemblance to lymphogranulomatosis The blood picture was normal

On admission a granuloma was found in the left external ear canal 1 cm lateral to the drum In the oral cavity a tumor infiltrating both upper and lower alveolar pro cesses of both sides although it was most pronounced on the left side was found In the maxilla it reached the midline of the hard palate It was most pronounced be tween the tonsil and the third mandibular molar tooth on the left side

Histologically there was a cell rich tissue consisting of middle sized [illegible] edged cells with no sharp limitations and of a light often finely granular cytoplasma The nuclei were round or slightly [illegible] with a fine chromatine structure Spread among these cells there was especially in some areas a very considerable amount of eosinophiles In other areas there were several capillaries so that the tissue was granulation like but mostly the tissue was so compact that there was no resemblance to normal granu

lation tissue Superficially infiltration of lympho- and leucocytes was found Th was sign of neither specific inflammation nor malignancy The cells of light cyt plasma mentioned were of the xanthom cell type This, together with the eosinophil seems to confirm the diagnosis of eosinophilic granuloma

X-ray examination showed a defect in the development of the molar teeth on bo sides of the mandible and there was a peculiar retraction of the marginal bord around the teeth It may be compared with a double sided follicular cyst depriming t border In addition an irregular cystic lesion of the left scapula was found and t medial ends of the femoral condyles were slightly frayed X-ray of the lungs w normal

Hemoglobin, sedimentation rate and blood picture were all within normal limi There was no eosinophilia There was a normal urinary output and the specific grav was also normal

The patient was treated with radiotherapy in a dosage of 500 r from both sides the jaw

Treatment was also instituted with corticotropine, in total 150 i u distributed ov 47 days

During treatment the tumor shrank The granuloma in the ear canal disappear and the process in the oral cavity left the gingival mucosa reddish in colour

The second admission (1956) to hospital took place 2½ months after the terminati of the first treatment A spongy granular thickening of the alveolar processes w found, and all the molar teeth were loose

This time corticotropine only was given in a total dosage of 285 i u distribut over 24 days

X ray examination at this time showed healing of the lesion in the left scapula

Six months later (1957) the patient was again admitted to the hospital with dent trouble This time no tumor was found and the lesion of the scapula had heal completely In cooperation with a dental surgeon the loose premolar teeth we extracted and a conserving treatment of the others was instituted, with due rega to a later prosthetic regulation

The last examination was in November 1960 The patient was at that time 7 years of age, 5 years after the beginning of the disease and 4 years after the termin tion of the treatment There was no sign of tumor, either in the ear or in the or cavity The dental occlusion was acceptable and the face appeared normally deve oped

DISCUSSION

A case is reported of a 3 year old boy with histologically verified eosino philic granuloma, localized to the maxilla, mandible, temporal bone an scapula Initially he was treated with radiotherapy and corticotropine Owin to a remaining and partly relapsing tumor 2½ months after the first treatme he was again submitted to treatment, this time with corticotropine only O this the tumor disappeared completely and there was no sign of relapse aft 4 years of observation

The value of the corticotropine treatment is difficult to evaluate owing t the possibility of spontaneous cure and the radiotherapy When howeve both the remaining tumor and the scapular lesions disappeared durin

treatment with corticotropine only one may consider it useful and worth trying in the future

It is obvious that an eosinophilic granuloma in the localization mentioned raises a problem concerning dentition and the maintenance of normal occlusion This is so much more important as the disease occurs at the age of dentition and development of the face Close cooperation with a dental surgeon is therefore of vital importance

ZUSAMMENFASSUNG

Das eosinophile Granulom ist zu den Retikulosen zu zahlen, was durch kurze Besprechung seiner Histologie und Symptomatik sowie an Hand einer Übersicht der wichtigsten Beiträge aus der otologischen und odontologischen Literatur dargestellt wird

Mitteilung eines Falles von e Gr der Mundhohle, der mit Rontgen und Corticotropin behandelt wurde Nach 4 Jahren kein Rezidiv

Besprechung der mit der Behandlung verbundenen Probleme

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STUDIES OF CRISTOSPINAL REFLEXES (LATEROTORSION)

II Caloric Nystagmus and Laterotorsion in Normal Individuals

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A previously reported method for simultaneously recording the cristo ocular (nystagmus) and cristo spinal (laterotorsion) reflexes is reviewed Calorically induced turning of the head, neck and body produced changes in weight on two pneumatic systems introduced beneath the head of supine individuals, which was expressed as laterotorsion This recording was made in addition to the usual nystagmus Such records were collected, studied and subjected to statistical analysis

Spontaneous laterotorsions of normal individuals were always less than 269 g after two minutes Caloric laterotorsion was always in the direction *of the slow component and averaged 828 g*

Maximum laterotorsion and nystagmus were fairly consistent for a given individual but varied between individuals

A statistical analysis revealed a significant correlation between vertigo and laterotorsion but not between vertigo and nystagmus

The lack of quantitative correlation between nystagmus and laterotorsion was evidenced by unequal patterns of behaviour which expressed itself as (1) lack of correlation between maxima of the two reflexes, (2) unequal time for development of the maxima and (3) unequal duration of the nystagmus and of the laterotorsion

Light decreases both nystagmus and laterotorsion The decrease of laterotorsion was less than that of nystagmus

The effect of vestibulo spinal reflexes on posture have been reported by *many authors (2 3 7 9 10 12–14 19 28)* Since these reflexes anatomically originate in both the macular and the ampullar apparatus it should be possible to study them separately

In a previous paper (17) the authors presented a method for adding to the nystagmus record a curve measuring the simultaneous cristo spinal responses (laterotorsion)

The method is based on a pneumatic system which records the pressure differences caused by the movements of the head These differences may be

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read directly from a manometer or from an electric recorder The differences in pressure are quantitative expressions of the magnitude of the turning movements of the head

Preliminary studies of such records indicate that nystagmus has a different pattern of behavior than laterotorsion This has led us to undertake the present study of laterotorsion and its relation to nystagmus and vertigo

Our sixfold aim was to study

I Spontaneous laterotorsion in light and darkness
II Caloric nystagmus and laterotorsion and their relation to vertigo
III The latency of caloric laterotorsion
IV The time for development of maximum laterotorsion and maximum nystagmus
V The duration of laterotorsion and nystagmus
VI The effect of light and darkness on caloric laterotorsion and nystagmus

METHODS

The technique for measuring the laterotorsion was fully described in a previous paper (17) The nystagmus was recorded by a derived technique earlier described by Henriksson (15 16) The vertigo was estimated by the patients and graded according to Lidvall (18) He used the following system

6 = Very intense turning sensation accompanied by a sensation of being thrown off the couch Unpleasant
5 = Intense turning sensation possibly slightly unpleasant
4 = Moderate turning sensation distinct in direction and plane Not unpleasant
3 = Mild turning sensation possibly not fully distinct in direction and plane
2 = No turning sensation but distinct sensation of rocking and swaying
1 = Vague sensation of rocking or swaying
0 No sensation of movement of the body in relation to the surroundings

Findings

I *Spontaneous laterotorsion in light and darkness*

Fifty normal individuals aged between twelve and fifty three years without any history of vertigo or hearing impairment were examined in order to study the spontaneous laterotorsion The movements of the normals were determined in the examining apparatus after one and two minutes both in darkness and in light This was repeated once to produce a total of 400 readings These readings were made simultaneously with recording of the eye movements which in all instances remained within the limits of normal

TABLE 1 *Spontaneous laterotorsion in darkness and in light after one and two minutes*

M = mean value S – standard deviation R = normal range according to 99 % level all expressed in grams t = significance level test Rt = turning towards right Lt = turning towards left

	Darkness		Light	
	1 min	2 min	1 min	2 min
M	6 Rt	15 Rt	15 Rt	18 Rt
S	76	98	69	10(
R	202 Rt – 190 Lt	269 Rt – 239 Lt	192 Rt – 162 Lt	292 Rt – 256 Lt
t	0 59	1 08	1 55	1 20

Statistical analysis of the readings of laterotorsion in these individuals are presented in Table 1

According to Table 1 spontaneous laterotorsion shows a mean of movement slightly to the right To find out whether this was significant the t test (8) was used

$$t = \frac{M\sqrt{n}}{S}$$

(n = number of observations) when the real mean value is supposed to be = 0 The t value according to the significance level of 10 % is 1 68 for n 30 As seen in Table 1 a significant t level for the tendency to lean towards the right is not reached in any group of determinations The possible influence of right or left handed dominance was not considered in this study A statistical analysis of the values for laterotorsion will thus show

1 Slight movements often occur spontaneously in the laterotorsion test
2 These movements are almost equally spread around zero In other words there is according to the t test no significant tendency to turn more in one direction than in the other
3 If these movements in darkness cause greater difference in pressure than 202 g after one minute and 269 g after two minutes it must be suspected that the tested individual does not have a normal system of equilibrium

II *Caloric nystagmus and laterotorsion and their relation to vertigo*

Twenty five normal individuals between fourteen and thirty eight years of age voluntarily submitted to caloric stimuli First the right and then the left ear canal was irrigated with water of 30°C and the irrigations were then repeated with water of 44°C The resulting nystagmus and laterotorsion were simultaneously recorded The examinations were conducted in darkness with the test subject s eyes open

The mean maximum eye speed and the mean maximum laterotorsion are presented as bargraphs in Fig 1 The eight columns on the left represent the average response to each type of irrigation the two columns on the right the

TABLE 2 *Maximum eye speed, maximum laterotorsion and degree of sensation (vertigo) of 25 normal individuals*

M = mean value S = standard deviation

	Nystagmus °/sec				Laterotorsion g				Vertigo[a]			
	30°C		44°C		30°C		44°C		30°C		44°C	
No	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt
1	31.7	39.7	31.7	30.2	1652	708	1593	944	4.0	4.0	4.0	4.0
2	33.3	33.3	25.3	20.0	354	354	472	177	2.0	2.0	2.0	2.0
3	30.0	31.5	36.2	31.6	118	177	236	472	2.0	2.0	2.0	2.0
4	26.3	36.5	30.6	26.3	354	236	236	118	1.0	1.0	1.0	1.0
5	25.0	25.0	18.3	13.3	354	826	708	354	4.0	2.0	2.0	2.0
6	20.0	14.7	10.7	10.7	590	826	354	826	2.0	4.0	1.0	4.0
7	17.0	19.8	14.2	14.2	944	708	472	1062	2.0	2.0	2.0	2.0
8	40.0	37.5	55.0	37.5	354	354	1652	1180	4.0	2.0	4.0	2.0
9	10.9	16.4	5.5	18.2	619	708	531	1062	0.0	2.0	1.0	4.0
10	31.7	31.7	48.0	48.0	708	1416	1888	826	2.0	2.0	1.0	1.0
11	36.4	36.4	37.3	35.5	2065	2301	4484	3540	5.0	5.0	6.0	6.0
12	29.8	31.6	31.6	29.8	1180	354	915	915	6.0	6.0	6.0	6.0
13	12.1	12.1	15.0	15.7	118	1770	2596	1652	3.0	4.0	3.0	4.0
14	19.1	26.5	17.6	20.6	1062	1180	531	590	3.0	4.0	3.0	3.0
15	20.0	20.0	17.5	21.3	295	236	295	177	4.0	4.0	4.0	4.0
16	24.0	30.0	30.0	28.0	797	826	1298	354	2.5	3.0	3.5	2.0
17	20.0	14.4	22.2	11.1	1180	590	885	885	3.0	3.0	3.0	2.0
18	25.3	24.0	25.3	24.0	826	1416	1534	177	4.5	4.0	5.0	3.0
19	20.0	18.7	18.7	17.3	354	708	885	236	4.0	1.0	3.0	4.0
20	12.5	12.5	7.5	15.0	649	590	590	236	4.0	4.0	4.0	4.0
21	62.5	35.0	65.0	62.5	708	295	207	266	4.0	3.0	3.0	4.0
22	37.8	33.3	42.2	32.2	1416	1888	1180	1357	4.0	4.5	4.0	4.0
23	16.8	19.6	27.1	24.3	531	472	236	6	4.0	4.0	5.0	5.0
24	31.2	31.6	30.8	31.6	354	236	236	236	2.0	1.0	2.0	1.0
25	37.0	35.2	35.2	35.2	1180	1180	413	826	4.0	4.0	4.0	4.0
M	27.1	26.8	27.9	26.3	752	814	977	769	3.2	3.2	3.1	3.2
S	11.4	8.9	14.4	12.1	489	572	961	715	1.4	1.3	1.1	1.5
M	26.9		27.1		783		873		3.2		3.2	
S	10.1		13.2		597		845		1.3		1.4	
M	27.0				828				3.2			
S	11.7				702				1.4			

[a] Vertigo graded from 0–6

averages of these All readings for laterotorsion nystagmus and degrees of reported vertigo are presented in Table 2

Analysis of these data shows

1 The hundred irrigations produced the predicted nystagmus and a simultaneous response of laterotorsion in the direction of the slow component

2 The mean laterotorsion caused by the hundred irrigations expressed as difference in weights on the balloons is 828 g The effect of irrigation will

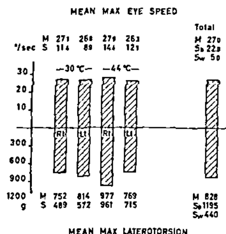


Fig 1 Diagrammatic representation of caloric nystagmus and laterotorsion in darkness of 25 normal individuals M = mean value, S = standard deviation, S_b standard deviation between individuals, S_w = standard deviation within individuals, Rt = irrigation of the right ear, Lt of the left ear

thus cause the average test person to twist and turn his head until he puts 828 g more weight on one of the balloons than on the other The corresponding mean of maximum eye speed is 27°/sec

3 The values both for maximum laterotorsion and for maximum nystagmus of the same individual shows a fair consistency indicating that each person has individual levels for both nystagmus and for laterotorsion The variation coefficients ($[S_w/M]$ 100) were 19 % for nystagmus and 53 % for laterotorsion

Variation coefficients between individuals ($[S_b/M]$ 100) were 81 % and 144 % respectively (S_w = standard deviation within individuals, S_b = standard deviation between individuals)

4 There was a significant quantitative correlation between vertigo and maximum laterotorsion but no such correlation between vertigo and nystagmus (see Table 3)

5 No quantitative correlation can be found between maximum nystagmus

TABLE 3 *The correlation coefficient between vertigo and maximum nystagmus and the correlation coefficient between vertigo and maximum laterotorsion with the corresponding t values*

r = correlation coefficient t significance level test ($t = r\sqrt{(n-2)/(1-r^2)}$)

		Vertigo	
Nystagmus	r	+0 0728	
	t	0 72	not significant ($P > 10$ %)
Laterotorsion	r	*+0 4118*	
	t	4 47	highly significant ($P < 0\,1$ %)

TABLE 4 *The time in seconds from onset of irrigation until maximum of nystagmus and maximum of laterotorsion has been reached*

M = mean value, *S* = standard deviation, *n* number of observations

	Nystagmus				Laterotorsion			
	30°C		41°C		30°C		44°C	
No	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt
1	70	77	56	66	104	100	124	109
2	58	54	53	56	108	138	108	101
3	56	70	54	54	132	105	136	139
4	48	62	58	70	101	154	124	102
5	68	61	49	65	147	153	140	82
6	59	66	69	68	171	147	98	120
7	65	54	68	62	114	149	82	88
8	65	72	61	57	137	109	112	106
9	55	77	81	72	150	126	125	125
10	66	64	61	65	139	121	77	118
11	73	70	64	62	79	96	94	109
12	69	77	57	61	149	131	104	—
13	54	74	68	65	122	104	—	94
14	57	67	63	66	114	115	117	112
15	61	56	55	57	97	85	108	107
16	52	56			129	121		
17	65	72			96	85		
18	59	59			166	143		
19	58	57			140	110		
20	68	69			131	—		
21	52	52			127	126		
22	55	51			101	119		
23	63	58			178	180		
24	51	65			172	137		
25	49	62			138	153		
26	70	51			104	91		
27	61	55			129	120		
28	72	63			182	202		
29	70	62			131	98		
n	29	29	15	15	29	28	14	14
M	61	63	61	63	131	126	111	108
S	7	1	8	5	27	28	19	15
M	62		62		128		109	
S	8		7		27		17	
M	62				122			
S	7				26			

and maximum laterotorsion the correlation coefficient being +0.1460. Hence the t value has no significance.

6. There is little change in the mean of maximum laterotorsion during the course of the four irrigations. Nor did maximum nystagmus show a definite change during these tests.

III. *The latency of caloric laterotorsion*

Our attempts to produce reliable figures for latency of caloric laterotorsion were unsuccessful. Random movements, protective movements caused by discomfort from the sudden contact with the irrigating water and the influence of the dim light used at the onset of the irrigation are all extralabyrinthine factors that overlap and obscure the findings especially during the beginning of the test. These difficulties have prompted a special study which is now in preparation.

IV. *The time for development of maximum laterotorsion and maximum nystagmus*

Examination of the curves shows that the eye speed reaches its maximum value much earlier than the laterotorsion its highest value (see Table 4).

The t values for the difference in time between maximum of laterotorsion and maximum of nystagmus have been calculated according to the formula

$$t = \frac{M_1 - M_2}{\sqrt{\dfrac{S_1^2(n_1-1)+S^2(n_2-1)}{n_1+n_2-2}}} \sqrt{\frac{n_1 \, n_2}{n_1+n_2}}$$

where the index 1 refers to laterotorsion and index 2 to nystagmus, n = number of observations.

The t values are:

<table>
<tr><th></th><th colspan="2">30° C</th><th colspan="2">44° C</th></tr>
<tr><th></th><th>Rt</th><th>Lt</th><th>Rt</th><th>Lt</th></tr>
<tr><td>t</td><td>13.49***</td><td>11.48***</td><td>9.31***</td><td>10.96***</td></tr>
<tr><td>t</td><td colspan="2">17.09***</td><td colspan="2">14.31***</td></tr>
<tr><td>t</td><td colspan="4">20.88***</td></tr>
</table>

*** Highly significant.

The difference in time between maximum of nystagmus and laterotorsion is highly significant.

The mean times for the nystagmus to reach its maximum is thus 62 ± 7 sec after onset of irrigation and 122 ± 26 sec for maximum laterotorsion. The difference is statistically highly significant.

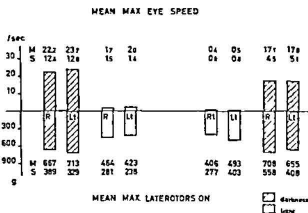


Fig 2 Diagrammatic representation of the influence of light on caloric nystagmus and laterotorsion Irrigations performed with water of 30 C Ten individuals irrigated first in darkness then in light and ten other individuals first in light and then in darkness *M* = mean value *S* = standard deviation Rt = irrigation of the right ear Lt of the left ear

V *The duration of laterotorsion and nystagmus*

The nystagmus reaction always disappeared between 120 and 150 seconds after onset of stimulus The laterotorsion however yielded a quite different pattern In all but five out of the 88 irrigations the laterotorsion outlasted the nystagmus At the endpoint of nystagmus there was still a considerable amount of laterotorsion which averaged 484 ± 399 g (see Table 5)

At the endpoint of nystagmus the decrease of laterotorsion in the curves was very slight and the laterotorsion in pilot examinations was frequently found to last for more than 10 minutes The determination of such endpoints would have destroyed the ability of the test subject to co operate for the remaining irrigations and was therefore avoided

VI *The effect of light and darkness on caloric laterotorsion and nystagmus*

Twenty normal individuals not previously exposed to vestibular stimuli had four irrigations of 30°C for 40 sec The irrigations were performed in a standard manner by stimulating first the right and then the left ear and then repeated in the same order Half of the examinations were performed first in darkness and then completed in light the remainder in the opposite order The averages of maximum eye speed and laterotorsion in darkness and in light are presented as bargraphs in Fig 2 and a statistical analysis of the findings shows

1 Caloric irrigation in light also produces laterotorsion in the predicted direction
2 The maximum laterotorsion is smaller in light than in darkness
3 The maximum eye speed is also smaller in light than in darkness
4 Light has a greater diminishing effect on nystagmus than it has on laterotorsion

Table 5 *Laterotorsion at the endpoint of nystagmus*

Laterotorsion in grams at the time when nystagmus ends. Nystagmus and laterotorsion induced by irrigation of water of 30° and 44°C for 40 sec in darkness. M = mean value, S = standard deviation, n = number of observations, t = significance level test

	30°C		44°C		
No	Rt	Lt	Rt	Lt	Total
1	266	177	0	263	
2	1180	1770	1062	1180	
3	649	325	177	207	
4	590	531	502	89	
5	295	679	708	89	
6	354	89	0	59	
7	413	354	0	502	
8	590	826	1180	0	
9	826	590	797	679	
10	561	295	738	148	
11	59	148	118	0	
12	649	295	59	531	
13	0	1475	—	1062	
14	826	148	649	708	
15	856	0	0	295	
16	738	885			
17	0	0			
18	472	236			
19	620	354			
20	1239	—			
21	443	561			
22	207	118			
23	443	649			
24	354	384			
25	1416	1003			
26	118	354			
27	118	236			
28	1092	1092			
29	620	295			
M	551	495	428	385	484
S	370	431	426	379	399
n	29	28	14	15	86
t	8.02***	6.07***	3.76**	3.93**	11.23***

t test has been used to evaluate the significance of the difference from zero of the laterotorsion values at the end point of nystagmus ($t = M\sqrt{n}/S$). It is seen that laterotorsion differs significantly (**) and highly significantly (***) from zero at the time when nystagmus ends.

DISCUSSION

Before caloric laterotorsion can be evaluated it is necessary to know the patterns (and amount) of spontaneous deviations. The records show that normals in darkness have random movements which after one minute have

caused pressure differences less than 202 g and by two minutes less than 269 g while caloric laterotorsion averaged 828 g.

The possibility that this marked difference is due to voluntary protective movements must be ruled out. Such protective movements are always directed away from the irrigated ear. Laterotorsion, however, occurs both towards and away from an irrigation depending on the temperature of the stimulus. Therefore protection cannot be regarded as the causative factor of the movements of laterotorsion.

An attempt was made to refine the test by leaving the connection between the two balloons open for the initial 3–4 sec of each irrigation. This in most cases minimizes the recording of protective movements but of course does not influence the protective movements in itself.

The variation of results obtained on repeated tests in the same individual can to some extent be attributed to protective movements adding to or subtracting from the genuine vestibularly induced movements. As both protective movements and the laterotorsion in hot water irrigations are always directed away from the stimulated ear these movements should therefore add to each other. In cold water irrigations, however, these movements are directed in the opposite direction and should subtract from each other. The relatively small influence of protective movements in the technique described is proved by the fact that the mean of laterotorsion caused by cold water is about the same as the mean of laterotorsion caused by hot water.

The variation of laterotorsion between different individuals proved to be definitely greater than that within individuals. This greater variability might be related to differences in sensitivity of the vestibular systems of various individuals but also to extra labyrinthine factors such as unequal muscle strength, psychic reaction and weight and shape of the head.

When a person exposed to the laterotorsion test responds to the stimulus and turns his head towards one side, more weight is placed on that balloon for two reasons. First, because of the turning the head will increase the pressure on that balloon. Second, the same turning will also shift the centre of gravity of the head towards that balloon, which will further increase the weight on it. Thus, the shape and the weight of the head influence the variability of laterotorsion between individuals.

It has long been known that there is only a poor quantitative correlation between sensation of vertigo and nystagmus (1, 6). This is also true in our findings. There is, however, a significant correlation between the amount of vertigo and of laterotorsion. We have a feeling that this should be interpreted cautiously because this correlation may not be true in each individual as it only expresses the average relationship between laterotorsion and vertigo.

In this material nystagmus and laterotorsion showed a qualitative but no quantitative relation. This is true in three instances. Firstly, the amounts of maximum nystagmus and maximum laterotorsion were entirely independent of each other. Secondly, the lengths of time for development of the maximum

point of the two responses were quite different Thirdly the duration of the laterotorsion was in most instances much greater than that of nystagmus

To test the effect of an extralabyrinthine factor visual impulses were introduced through examination in light Both nystagmus and laterotorsion diminished but there was no parallelism between their decrease the nystag mus being affected much more than the laterotorsion This again illustrates the difference in behaviour of cristo spinal and cristo ocular reflexes

A labyrinthine impulse travelling through the two reflex arcs is thus affected differently by extralabyrinthine factors creating two independent responses Thus a new set of measurements can be introduced along with nystagmus to help to analyze equilibrium in normals and abnormals

Wodak & Fischer (29) carefully observed and reported the turning twisting and tilting movements of a standing person s body following caloric stimulation We found that similar movements also exist when the patient is stimulated in a supine position If the examiner stands behind the recumbent subject and balances the person s head in his hands he will feel these move ments shifting the weight of the head from one hand to the other

As pointed out in this paper the role of the cristo spinal tract has been interpreted by devices for recording the induced movements following caloric irrigation Once this role has been established clinicians can roughly gauge these reflexes by estimating the movements of the head which they would hold during the caloric test The increased accuracy of a pneumatic system and a manometer could still be applied during a clinical caloric test

Despite arguments over details anatomists ([illegible]) agree that the labyrinth connects with the spinal cord via three main tracts the vestibulo and the reticulospinal tracts as well as the medial longitudinal fasciculus Neuro physiologists (11) seem to be able to follow responses to stimuli over such tracts It is therefore felt that a clinical study of the behavior of vestibulo spinal reflexes in abnormal subjects and the effect of habituating the re sponses in normal subjects may further elucidate the contribution of these tracts to posture Studies of these will soon be presented

RÉSUMÉ

Il a déjà été rendu compte d une méthode d enregistrement simultané des réflexes cristo oculaires (nystagmus) et cristo spinaux (latérotorsion) La rotation de la tete du cou et du corps produite par un stimulus calorique a occasionné des change ments de poids chez deux systèmes pneumatiques introduits sous la tête des patients allongés ce qui a été exprimé en latérotorsion Ces enregistrements ont été faits en addition au nystagmus ordinaire Ils ont été rassemblés étudiés et soumis à une analyse statistique

La latérotorsion spontanée normale a toujours été inférieure à 269 g La latéro torsion calorique allait toujours dans la direction de la composante lente et était en moyenne de 828 g

La latérotorsion et le nystagmus maxima étaient à peu près constants pour un individu donné mais variaient suivant les individus

Une analyse statistique a mis en corrélation le vertige avec la latérotorsion mais non avec le nystagmus

La différence entre le nystagmus et la laterotorsion a été mise en évidence quantitative par l'inégalité des modeles de comportement et s'exprimait ainsi (1) manque de corrélation entre maxima des deux réflexes (2) inegalité de temps pour atteindre le maximum (3) inégalité de duree du nystagmus et de la latérotorsion Le décroissement de la latérotorsion était inférieure à celle du nystagmus en lumiere

ZUSAMMENFASSUNG

Eine vorher mitgeteilte Methode zur gleichzeitigen Registrierung der cristo ocularen (Nystagmus) und cristo spinalen (Laterotorsion) Reflexe wird besprochen Kalorisch induzierte Drehung des Kopfes, Nackens und Korpers ruft Veranderungen in der Belastung zweier luftgefullter Systeme hervor, die unter dem Kopfe liegender Versuchspersonen angebracht werden Dieses wurde als Laterotorsion bezeichnet und die Registrierung zusatzlich zum gewohnlichen Nystagmus ausgefuhrt Solche Messungen wurden gesammelt, ausgewertet und statistisch analysiert

Spontane Laterotorsion war bei der normalen Versuchsperson immer geringer als 269 g Kalorische Laterotorsion trat immer in Richtung der langsamen Komponente auf und betrug im Durchschnitt 828 g

Das Maximum der Laterotorsion und des Nystagmus war ziemlich konstant bei ein und derselben Versuchsperson aber variierte zwischen verschiedene Personen

Eine statistische Analyse korrelierte Vertigo mit Laterotorsion aber nicht mit Nystagmus

Der quantitative Unterschied zwischen Nystagmus und Laterotorsion wurde durch ungleiches Verhalten augenscheinlich gemacht Dieses kam zum Ausdruck durch (1) mangelnde Korrelation zwischen den Maxima der beiden Reflexe (2) verschiedene Zeit für die Enstehung der Maxima und (3) verschiedene Dauer von Nystagmus und Laterotorsion

Licht verringert sowohl Nystagmus als auch Laterotorsion Die Abnahme der Laterotorsion war dabei geringer als die des Nystagmus

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ZUR FRAGE DER SCHALLÜBERTRAGUNG DURCH DAS MITTELOHR

Versuch einer akustischen Messung

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An frischen Schläfenbeinen wurde die Schalleitung durch das Mittelohr studiert Als Schallquelle diente ein Reintonaudiometer Der Schall wurde durch den äußeren Gehörgang zugeführt und im Vestibulum des Innenohres auf elektroakustischen Wege gemessen Nach artifiziell gesetzter Störung der Kettenfunktion durch Aufklappen des Trommelfelles trat eine Verminderung der im Innenohr abgelesenen Schallenergie auch bei der Prüfung höherer Töne bis 4000 Hz ein Damit scheint die Gehörknöchelchenkette eine gewisse Transmissionsfunktion auch für Töne im höheren Frequenzbereich zu besitzen

Mit der Zunahme unserer Kenntnisse auf dem Gebiet der Hörphysiologie wird auch der Frage nach der Schalltransmission durch das Mittelohr eine gesteigerte Beachtung geschenkt In quantitativer Hinsicht handelt es sich um die Größe der Schalldrucktransformation in das Innenohr qualitativ steht der scheinbar vom Frequenzcharakter des Schalles abhängige Übertragungsweg in das Perzeptionsorgan zur Debatte Unter ganz besonderer Berücksichtigung der anatomischen Details der Gehörknöchelchen wurde bei den experimentellen Untersuchungen an menschlichen Schläfenbeinen bisher besonderer Wert auf die Feststellung der Drehungsverhältnisse und der Schwingungsamplitude der Mittelohrkette unter dem Einfluß zugeführter Schallenergie gelegt Diese Bewegungsmomente an Trommelfell Hammer Amboß oder Steigbügel ließen sich optisch (Dahmann Wanderer v Bekesy u a) elektromagnetisch (Perlmann) und mit der kapazitativen Sonde (v Bekesy) registrieren Diesen Untersuchungen verdanken wir einen Großteil unseres heutigen Wissens über die Mittelohrfunktion sie waren aber auch Grundlage und Wegbereiter für die moderne gehörrestaurierende Mittelohrchirurgie

Während die verschiedenen Modifikationen der Tympanoplastik Operationen im Mittelohr (Moritz Wullstein Zöllner u a) diese funktionellen Erkenntnisse berücksichtigen geht die Entwicklung der hörverbessernden Steigbügeloperationen an Otosklerosepatienten scheinbar ihren eigenen Weg Diese Entwicklung basiert auf der Erfahrung daß nach operativem Ersatz der Steigbügelfußplatte durch Binde- oder Gefäßgewebe (Zangemeister

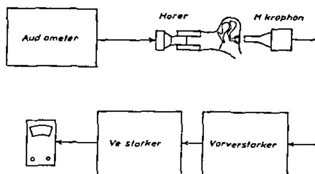


Abb. 1. Prinzipschaltbild der Versuchsanordnung

Portmann u. a.) ja selbst nach Ersatz des Rest-Stapes durch eine Kunststoffprothese (Shea) optimale Transmissionsverhältnisse im Mittelohr wieder hergestellt werden. Eingedenk der komplizierten anatomischen Form des Steigbügels und der besonderen Schwingungsarten seiner Fußplatte (v. Békésy u. a. Wanderer) kommt diese Tatsache um so überraschender, als wir ja gewohnt sind, daß die Natur so sparsam als möglich baut.

Es schien uns deshalb von Interesse, experimentell zu untersuchen, wie sich die Schalldrucktransformation nach operativ gesetzten Veränderungen im Mittelohr verhält. Da wir ursprünglich vor allem die experimentelle Reproduktion der Steigbügeloperationen im Auge hatten, erachteten wir die eingangs erwähnten optischen, kapazitativen oder elektromagnetischen Prüfsysteme für unsere Untersuchungen aus rein technischen Gründen als wenig geeignet. Aus diesem Grunde entschieden wir uns für die akustische Messung der Schallübertragung, wobei wir ihre Abnahmestelle in das Vestibulum des Innenohres des menschlichen Felsenbeines verlegten. Wie v. Békésy feststellen konnte, verändert der Tod bei Verwendung frischer Leichenpräparate die mechanischen Eigenschaften des Ohres kaum. Diese Feststellung genügt als Voraussetzung für unsere Untersuchungen, die, weitab von jeder hörphysiologischen Erwägung, allein auf die Mechanik der Schalleitung durch das Mittelohr ausgerichtet sind.

Für die Untersuchungen wurden möglichst frische Schläfenbeine verwendet. Bis zur Verwendung wurden diese in feuchtem Milieu bei Kühlschranktemperatur aufbewahrt, um so ein Austrocknen oder eine Zersetzung zu verhindern, wodurch unter Umständen falsche Untersuchungsergebnisse zu erwarten gewesen wären. Dem äußeren Gehörgang wurden nun von einem Tonaudiometer die entsprechenden Prüftöne durch einen Gummischlauch zugeführt (Abb. 1). Der Schlauch wurde möglichst kurz gewählt, um Intensitätsverluste der Prüftöne zu vermeiden. Weiters war auf einen guten Abschluß im Gehörgang zu achten, um das Austreten von Schall zu verhindern, was bei besonders starken Intensitäten zu direkter Erregung des Mikrophones und dadurch zu Fehlmessungen führen konnte. Zum Zwecke der Tonintensitätsmessung auf der labyrinthären Seite des Steigbügels wurde vor Beginn des jeweiligen Versuches der innere Gehörgang des Schläfenbeines

Abb. 2. Topographie der Versuchsanordnung. Schallzufuhr durch den äußeren Gehörgang. Schallabnahme im Innenohr

aufgebohrt und das Vestibulum eröffnet (Abb. 2). Geht man dabei so vor, daß man das Vestibulum in gerader Verlängerung des inneren Gehörganges eröffnet, wobei ein Teil der Crista transversa abgetragen wird, so gelangt man genau gegenüber der Steigbügelplatte in das Labyrinth. Nach sorgfältiger Entfernung des Bohrstaubes wurde sodann ein 3 mm starkes Kunststoffröhrchen in einer Entfernung von 2 mm von der Steigbügelplatte eingesetzt und dieses mit Phosphatzement fixiert, so daß der Zugangsweg zwischen dem Plastikrohr und dem Knochen vollständig ausgefüllt wurde. Dadurch erfolgte ein sehr guter schalldichter Abschluß und außerdem bestand keine Gefahr, daß das Röhrchen durch die Manipulation im Laufe des Versuches in seiner Lage verändert hätte werden können. Dieses Röhrchen stand unmittelbar mit einem Kunststoffgehäuse in Verbindung, in dem sich ein elektromagnetisches Mikrophon befand, das zur Abschirmung äußerer Schalleinwirkungen vollständig in schalldämmendes Material gebettet war und nur durch einen schmalen Kanal mit dem Röhrchen in Verbindung stand. Das Mikrophon war an einen dreistufigen Verstärker angeschlossen, an dessen Ausgang ein Wechselspannungsmeßgerät ein bequemes Ablesen der aufgenommenen und verstärkten Schallenergie ermöglichte. Um Manipulationen am Trommelfell und im Mittelohr während des Versuches unter dem Mikroskop durchführen zu können, wurde das Schläfenbein in einer Haltevorrichtung fixiert. Da während der Durchführung der Versuche eine konstante Verstärkerleistung gefordert werden mußte, wurde jeweils am Beginn der Versuche und auch mehrmals zwischendurch die gesamte Apparatur mittels eines bekannten Testtones, der dem Audiometer entnommen wurde, auf einen bestimmten

Tabelle 1 *Frequenzabhängige Abnahme der Schallenergie (in db) nach operativer Eröffnung des Mittelohres*

Die zugeführte Schallenergie beträgt 90 db Die Schallmessung erfolgt im Innenohr

Geprüfte Tonfrequenzen in Hz	500	1000	1500	2000	3000	4000
Verminderung der Schallenergie in db	8 2	7 6	11 1	12 7	12 0	8 8

Ausschlag gereicht Auf Grund der Versuchsanordnung bestand eine Massenbelastung des Steigbügels wie sie normalerweise durch Labyrinthflüssigkeit und Elastizität der Membran des runden Fensters gegeben ist nicht Ein Einfluß auf die Elastizität der schwingenden Gehörknöchelchenkette wäre daher naheliegend Nach Frank wird der Massenverlust jedoch nur mit 10% der Masse der Gehörknöchelchen angegeben so daß eine Veränderung des schwingenden Systemes im Sinne der Übertragungsleistung durch fehlende Liquorbelastung als höchstens geringfügig anzusehen ist

Bei den Versuchen wurde nun so vorgegangen daß grundsätzlich alle Audiometertöne im Sprachfrequenzbereich dem äußeren Gehörgang zugeführt wurden Insbesonders untersuchten wir die Frequenzen 500 1000 1500 2000 3000 und 4000 Hz Um dabei exakt meßbare Ausschläge am Meßinstrument zu erhalten mußte die Tonintensität des Audiometers auf 80 und 90 db eingestellt werden Wohl konnte man im Bereich von 2000 Hz in der Regel bei Schallintensitäten von ca 65 db schon meßbare Ausschläge registrieren sie waren jedoch zu gering um sie im Versuch praktisch auswerten zu können

Obwohl bei dem Versuch ein Audiometer (Maico) mit abgestuftem Intensitätsregler benutzt wurde dessen Intensitätsstufen jeweils 5 db betrugen konnte mit dieser Apparatur eine Meßgenauigkeit von 1 db erzielt werden Dies war deshalb möglich weil man bei Intensitätsunterschieden von 5 db einen derart großen Ausschlag am Meßgerät bekam daß die Skala leicht in 5 energetisch gleich große Teile (Berücksichtigung des logarithmischen Wertes) unterteilt werden konnte

Die Messung erfolgte auf zwei Arten

Bei der ersten Methode wurde bei jeweils 80 und 90 db der Zeigerausschlag des Meßgerätes registriert und die Zu oder Abnahme der Schallenergie in db errechnet Bei der zweiten Methode wurde mit Hilfe des Audiometers auf einen bestimmten Wert der Skala eingestellt und dieser Ausgangswert nach den entsprechenden Eingriffen am schalleitenden Apparat mittels des Potentiometers wieder zu erreichen getrachtet Bei Gegenüberstellung beider Befunde fanden sich vollkommen gleiche Ergebnisse

Bei allen Versuchen erzielten wir im Bereich der niederen Tonfrequenzen vor allem bei 500 1500 Hz geringere Ausschläge bzw mußten wir die Intensität des Prüftones erhöhen um die festgelegten Werte zu erreichen Wie Messungen ohne Knochenpräparat ergaben war dies auf eine Eigenart

der Versuchsanordnung zurückzuführen bei der vor allem Resonanz und Dämpfungseigenschaften im Schallzuleitungsteil der Anlage eine besondere Rolle spielten In Anbetracht dessen daß unsere gesamten Untersuchungen sich ausschließlich auf Relativmessungen bezogen konnte dieser Umstand völlig unberücksichtigt bleiben

Die erforderlichen Messungen führten wir an insgesamt 12 Schläfenbeinen durch Dabei gingen wir so vor daß wir vorerst die Lautstärke der Prüftöne die zum Ansprechen des Meßgerätes führten feststellten Anschließend registrierten wir dann bei 80 und 90 db die den jeweiligen Frequenzen zugehörigen Skalenausschläge Sodann eröffneten wir nach Entfernung des Hörers unter Verwendung eines Auflichtmikroskopes das Mittelohr Dabei wurde nach der von Lempert angegebenen Methode vorgegangen und nach Incision der häutige Teil der hinteren Gehörgangswand vom Knochen abgetrennt der Anulus tympanicus aus dem Falz gelöst und nahezu die gesamte hintere Trommelfellhälfte nach vorne geklappt Hierauf wurde wieder der Schallgeber eingesetzt und die Messung mit 80 und 90 db wiederholt Es zeigte sich dabei wie aus Tabelle 1 ersichtlich daß es zu einem deutlichen Absinken der auf der labyrinthären Seite aufgenommenen Schallenergie in allen geprüften Frequenzen des Sprachbereiches gekommen war Nach Rückklappen des Trommelfelles konnten in allen Frequenzen wieder nahezu die Ausgangswerte erzielt werden Die Messungen erbrachten bei allen Präparaten (mit Ausnahme von zweien) sehr konstante Werte Bei diesen beiden waren die Ergebnisse so unterschiedlich daß pathologische Veränderungen des Schalleitungsapparates angenommen werden mußten Tatsächlich fanden sich auch bei Eröffnung des Mittelohres Zeichen einer chronischen Entzündung

Die Stärke der Schalldrucktransformation des intakten Mittelohres nimmt nach v Békésy zwischen Gehörgangsöffnung und Steigbügelfußplatte in den Frequenzen von 500 bis 2000 Hz zu um dann abzufallen Der Wert der Drucktransformation liegt in diesem Bereich bekanntlich um 22 Diese Untersuchungsergebnisse entsprechen der heute geltenden Ansicht daß die Schallübertragung durch das Mittelohr ihren optimalen Wirkungsgrad nur bei tiefen und mittleren Tönen erreicht Dafür sprach auch die Beobachtung v Békésys daß die Schwingungsamplitude des Steigbügels bei konstantem Schalldruck ausgesprochen frequenzabhängig ist da sie bis etwa 2000 Hz proportional mit der Frequenz abnimmt um im höheren Tonbereich steil abzufallen

Wir erwarteten daher von unseren vergleichenden Untersuchungen daß sich nach einer artefiziell erzeugten Störung der Kettenfunktion im Mittelohr die abgelesene Schallenergie im Innenohr nur bei den tiefen und mittleren Frequenzen bis um 2000 Hz verringern würde Das Aufklappen des Trommelfelles muß durch die damit verbundene Reduzierung seiner Gesamtfläche auf ungefähr die Hälfte ja als eine solche Störung angesehen werden Der im Vestibulum labyrinthi abgenommene Schalldruck nahm darauf aber nicht in einzelnen sondern in sämtlichen geprüften Frequenzbereichen ab Wohl

lag die Spitze der in db gemessenen Schalldruckdifferenz bei 2000 Hz, sie war aber auch bei 3000 Hz und etwas schwächer auch bei 4000 Hz noch deutlich vorhanden Da nach Rückklappen des Trommelfelles in seine normale Lage stets wieder annähernd die Ausgangswerte des Schalldruckes vermerkt werden konnten mussen wir seine Abnahme auf die experimentell verminderte Transmissionsfunktion der Gehorknochelchenkette zurückführen Damit scheint ihre funktionelle Bedeutung aber auch fur die Übertragung hoherer Tone, wie etwa 4000 Hz bewiesen Die Prufung noch hoherer Frequenzen mußten wir uns aus Grunden, die in der Charakteristik des verwendeten Mikrophones liegen, leider versagen Wegen der zu geringen Empfindlichkeit des Mikrophones konnten wir letzlich auch keine schallenergetische Messung nach Steigbugeloperationen am Praparat durchfuhren Es ware dafur ein Eingangsschalldruck notwendig gewesen, dessen Großenordnung das Leistungsvermogen des Audiometers ubersteigt Ähnlich hohe Tonintensitaten waren aber auch fur Untersuchungsanordnungen anderer Autoren nötig Wahrend unsere akustische Messung ab einer Lautstarkezufuhr von 80 db verwertbare Resultate erbrachte, konnte Perlmann die Oszillationen der Gehorknochelchen erst ab 100 db registrieren

Kunftige Versuche in dieser Richtung setzen also eine Verfeinerung jener Meßgeräte voraus mit deren Hilfe wir auf elektroakustischem Wege die Mechanik der Schallubertragung durch das Mittelohr exakt studieren konnen Unsere derzeitigen Anstrengungen gelten dem Bestreben, operativ gesetzte Veränderungen an der Mittelohrkette auch bei Verwendung geringerer Schallenergie zu erfassen Durch die geradezu sturmische Entwicklung der Steigbugelchirurgie trat in klinischer Sicht eine Reihe offener Fragen auf deren Beantwortung wir auf diese Weise auch experimentell zu versuchen hatten

SUMMARY

The transmission of sound through the middle ear was studied on fresh temporal bones The source of sound was a clear tone audiometer The sound was transmitted through the external meatus and measured acoustically in the vestibulum of the labyrinth After interfering artificially with the function of the chain of ossicles by opening the drum the energy of sound measured in the labyrinth was reduced even with higher frequencies up to 4000 cps Thus we came to the conclusion that the chain of ossicles seems also to be transmitting sounds of higher frequencies

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HABITUATION, EFFERENCE AND VESTIBULAR INTERPLAY

II. Combined Caloric Habituation

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Following an initial caloric test in each of five subjects, the right ear was habituated by repeated irrigation tests at 44°C. The result was checked by a further caloric test. Four of the subjects then underwent secondary habituation of the right ear with water at 30°C, and the fifth, of the left ear at 44°C. The outcome was studied by means of a final caloric test.

Primary habituation elicited directional preponderance to the left; secondary habituation involved a reversal, with preponderance to the right, whether the right ear was habituated to cold water or the left ear to hot water. The initial habituation was associated with secondary nystagmus to the left, but on secondary habituation its direction was reversed. The nystagmograms showed concurrent characteristic dysrhythmia, which was also altered by secondary habituation. These results are attributed to regular changes in the efferent activity of the two labyrinths.

In a previous investigation (Fluur & Mendel, 1962) we showed that monaural habituation by irrigation with water at 30° or 44°C modifies the responsiveness of the two labyrinths. Two different types of labyrinthine responses were observed. In one group directional preponderance towards the ipsilateral ear after cold water habituation and towards the contralateral ear after hot water habituation was observed, while in the other group the duration of nystagmus was bilaterally reduced following both cold water and hot water irrigation.

The consensus in the literature is that habituation to a stimulus usually persists for relatively long periods—up to several months—and this has been found to be true of the vestibular apparatus. We thought it of great interest, therefore, to investigate the possibility of inducing in an already habituated organ a second habituation with a reversed effect.

MATERIAL AND METHODS

Five subjects with no record of equilibrium disturbances underwent, prior to habituation, caloric tests *ad modum* Hallpike *et al.* (1942). The right ear was then subjected to repeated irrigation with water at 44° for 30 second

periods after which the duration of nystagmus was recorded with an electronystagmographic technique, via an electrode attached to the outer canthus of each eye The habituation series comprised eight to twelve irrigation tests and was followed by a further caloric test to establish the post habituation level of activity in the two labyrinths

Four of the subjects were then submitted to a fresh irrigation series in which the right ear was habituated with water at 30°C the mode of procedure was as before After six to ten irrigations accompanied by nystagmus recording a final caloric test was performed in order to establish what changes the labyrinthine response had undergone

After primary hot water habituation of the right ear we induced in the fifth subject secondary hot water habituation of the left ear instead in order to see if the effect would be the same as that occurring after the above mentioned secondary habituation of the right ear to 30°C

RESULTS

Each of the five selected subjects was referable to the category called group 1 in our previous paper which is to say that habituation was attended by changes in the activity of the two labyrinths At the initial post habituation test the change was manifested by a distinct directional preponderance towards the left and in one subject by spontaneous nystagmus in the same direction (Table 1)

TABLE 1 *Duration of nystagmus after primary habituation of right ear to 44°C and secondary habituation of right ear to 30 or left ear to 44*

		Prehabituation duration of nystagmus		Duration of nystagmus after habituation to 44 C		Duration of nystagmus after habituation to 30 C	
		30 C	44 C	30°C	44 C	30 C	44 C
				RIGHT EAR HABITUATION		RIGHT EAR HABITUATION	
No 1	R	184	202	spont nyst	142	[illegible]	[illegible]
	L	238	[illegible]	200	spont nyst	[illegible]	[illegible]
No 2	R	122	134	158	[illegible]	130	146
	L	134	115	116	186	[illegible]	138
No 3	R	170	[illegible]	192	104	101	[illegible]
	L	[illegible]	[illegible]	112	194	[illegible]	140
No 4	R	130	146	[illegible]	90	6	122
	L	124	138	40	180	[illegible]	142
				RIGHT EAR HABITUATION		LEFT EAR HABITUATION	
No 5	R	102	134	208	[illegible]	[illegible]	156
	L	94	[illegible]	[illegible]	[illegible]	158	124

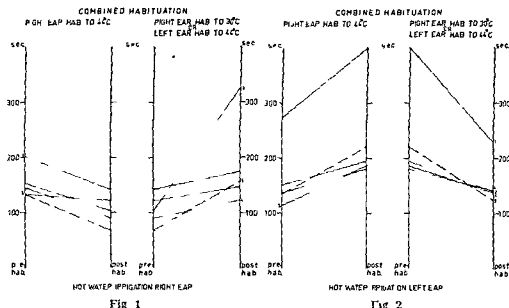


Fig 1

Fig 2

Fig 1 Duration of nystagmus on hot water irrigation of right ear following (left) primary habituation of that ear to 44°C and (right) secondary habituation of same ear to 30°C (continuous line) or of contralateral ear to 44°C (broken line) The duration has decreased after the initial habituation but has increased again after the second

Fig 2 Duration of nystagmus on hot water irrigation of left ear following (left) primary habituation of right ear to 44°C and (right) secondary habituation of right ear to 30°C (continuous line) or of left ear to 44°C (broken line) The duration has increased after the initial habituation but has decreased again after the second

In the course of secondary cold-water habituation of the right ear, the duration of nystagmus progressively decreased with each succeeding test At the secondary post-habituation test hot-water irrigation of the right ear produced nystagmus of much longer duration (Fig 1), and cold water irrigation nystagmus of shorter duration (Fig 3), than that which followed the primary post habituation test

The non-habituated contralateral ear, which had shown a better response to hot water irrigation after the primary habituation, showed a smaller response after the secondary habituation (Fig 2) The cold water test of this ear produced nystagmus of shorter duration following primary habituation and of longer duration after secondary habituation (Fig 4)

In the subject who had undergone secondary hot water habituation of the left ear post habituation irrigation produced an effect fully consistent with that resulting from secondary cold water habituation of the right ear

Following the primary habituation three subjects had secondary nystagmus towards the left after hot water irrigation of the right ear or cold-water irrigation of the left On secondary habituation however, the direction of the nystagmus movements, which followed hot water irrigation of the left ear

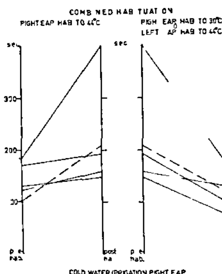


Fig 3

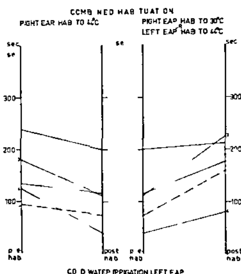


Fig 4

Fig 3 Duration of nystagmus on cold water irrigation of right ear following (left) primary habituation of right ear to 44 C and (right) secondary habituation of right ear to 30 C (continuous line) or of left ear to 44 C (broken line) The duration has increased after the initial habituation but has decreased again after the second

Fig 4 Duration of nystagmus on cold water irrigation of left ear following (left) primary habituation of right ear to 44 C and (right) secondary habituation of right ear to 30 C (continuous line) or of left ear to 44 C (broken line) The duration has decreased after the initial habituation but has increased again after the second

or cold water irrigation of the right was reversed This phenomenon was observed in two subjects after secondary cold water habituation of the right ear and in one after secondary hot water habituation of the left

Subsequent to the primary hot water habituation all five subjects had dysrhythmia chiefly after right ear irrigation at 30°C and left ear irrigation at 44°C (Fig 5) The secondary habituation altered the pattern of this dysrhythmia so that in the final test it was observed mainly after cold water irrigation of the left ear and hot water irrigation of the right

Examination of the complete results disclosed variations in the number of nystagmus movements which while not uniform for all subjects frequently showed a striking consistency The nystagmograms at the post habituation test following hot water habituation of the right ear exhibited a reduced number of movements per unit time (10 sec) on right ear irrigation at 44° and on left ear irrigation at 30°C On hot water irrigation of the left ear and cold water irrigation of the right however the number of nystagmus movements exceeded that recorded at the pre habituation test After secondary habituation the frequency pattern was completely changed being the reverse of that noted after primary habituation (see Fig 5)

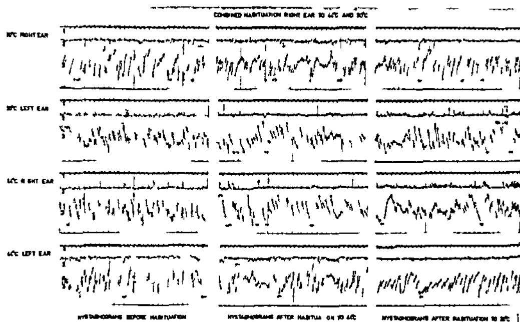


FIG. 5. Nystagmograms before and after combined habituation of right ear to 44° and 30 C. Following primary habituation to 44°C, the nystagmograms from 30° irrigation of right or 44° irrigation of left ear show an increased number of movements per unit time, as well as pronounced dysrhythmia. Following secondary habituation to 30°, the nystagmogram from 30° irrigation of right ear shows a reduced number of movements per unit time, as well as less pronounced dysrhythmia. The number of movements is also decreased after 44° irrigation of left ear, but no pronounced dysrhythmia is present. After primary habituation to 44° the nystagmograms from 30° irrigation of the left ear or 44° irrigation of the right show a decreased number of movements per unit time but no marked dysrhythmia. After secondary habituation, however, the number of movements is increased and dysrhythmia appreciable.

DISCUSSION

The investigation indicates that in a person already habituated by repeated monaural irrigation with hot water it is not possible to superimpose a habituation to cold water in the same ear without influencing the response to the primary habituation. This finding conflicts with the results of cat studies reported by Henriksson *et al.* (1961) who observed that nystagmus towards both the right and the left decreased after monaural habituation with hot (48°C) and with cold (20–28°C) water. They drew the conclusion that habituation of nystagmus in one direction has little or no effect upon habituation of nystagmus in the opposite direction. Their divergent finding may be explained by the fact that, due to the major differences in water temperature, a caloric test in the cat elicits so intense an arousal reflex that the reticular formation suppresses the activity of both labyrinths (Duensing & Schaefer 1957).

Most authors who have studied the habituation problem find that once habituation has developed it may persist for weeks or even months. One

thus gains the impression that habituation is a conditioned response pattern which tends to persist with repetition of impulses of the same type within a certain limited period The present investigation has shown that this behavior pattern far from being stable can be modified even to the point of complete reversal Hot water habituation of the right ear is attended by an increase in the efferent activity leading to an ipsilateral elevation of the hyperpolarization pressure coincident with a decrease in the contralateral efferent activity and hence an elevation of the depolarization pressure When after primary habituation of the right ear secondary habituation of that ear is produced with cold water the previously induced increase of efferent activity and with it the elevated hyperpolarization pressure gradually change character so that the efferent activity diminishes and a higher depolarization pressure occurs in the peripheral labyrinth In the contralateral labyrinth—which after the primary hot water habituation has a reduced efferent activity and an elevated depolarization pressure—the secondary cold water habituation of the right ear modifies the polarization conditions via augmentation of the efferent activity the result being a higher hyperpolarization pressure Accordingly cold water irrigation produces nystagmus of longer and hot water irrigation nystagmus of shorter duration—as evidenced in this investigation

When the subject had undergone hot water habituation of the right ear it was possible to influence the resulting change of polarity so that the final result was the same whether secondary habituation was produced in the ipsilateral ear with cold water or in the contralateral ear with hot water This observation suggests that the terminal whose activity has been modified at the primary habituation can be consistently influenced secondarily from both labyrinths though by opposite stimuli—a hypothesis which lends weight to the view (Fluur & Mendel 1962) that the afferent activity of one labyrinth influences the efferent activity of the other The following physiologic mechanism may therefore be postulated Primary hot water habituation of the right ear has served to raise the efferent activity The latter can be inhibited again either by ipsilateral cold water habituation or by contralateral hot water habituation In the latter instance the contralateral efferent activity—*i e that of the initially habituated labyrinth—is reduced via the reciprocal* mechanism In both instances an elevation of the depolarization pressure occurs on the right side entailing in turn a longer duration of nystagmus on hot water irrigation of the right ear and a shorter duration on cold water irrigation The investigation corroborates this hypothesis

Those subjects who after hot water habituation of the right ear showed spontaneous or secondary nystagmus towards the left exhibited on secondary habituation secondary nystagmus towards the right The inference is that habituation affects the spontaneous activity levels in the two labyrinths and disrupts the balance between them The subjects invariably show secondary nystagmus towards the side on which due to the habituation the depolarization pressure is elevated via inhibition of the efferent activity This phenomenon may well be responsible for the characteristic changes

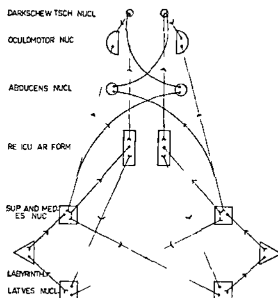


Fig. 6. Afferent and efferent vestibular pathways.

of frequency observed after the various types of habituation. The frequency of nystagmus movements is always greatest in the direction of the secondary nystagmus.

Primary hot water habituation was followed by dysrhythmia which was associated chiefly with nystagmus movements in the same direction as the secondary nystagmus. Secondary habituation altered this pattern insofar as dysrhythmia was absent after the irrigation tests which caused nystagmus towards the right, but was demonstrable after cold water irrigation of the left ear and hot water irrigation of the right. Here too, therefore, dysrhythmia was most common when the nystagmus movements were in the same direction as the secondary nystagmus. The implication is that the dysrhythmia is intimately associated with the habituation process as such and is due to the disturbance in the functional equilibrium of the two labyrinths.

The question now arises as to the localization of the processes which lead to habituation. Do they originate at nuclear level, as seems to be the case in compensation following labyrinthine destruction, or in the peripheral labyrinth? Rasmussen & Gacek (1958) and Gacek (1961) have shown that efferent nerve fibers arise in the lateral vestibular nucleus. Jansen & Brodal (1940) identified fibers from several different cerebellar centers that terminated precisely in the lateral vestibular nucleus, and Thomas *et al.* (1956) reported detailed studies of the latter's communications with the fastigeal nucleus. The studies of Cajal (1909, 1911) and Lorente de Nó (1933) have shown that fibers also pass from the pontine and medullary reticular formation to the

vestibular nuclei The above mentioned anatomic data suggest that impulses from the reticular formation and the cerebellum unite in the lateral vestibular nucleus to form a single efferent pathway which terminates in the granulated nerve endings beneath the vestibular sensory cells Habituation could thus develop in any one of three ways via the cerebellum from the contralateral labyrinth via the reticular formation or, possibly via direct communications between the two vestibular nuclei by secondary fibers Such a mechanism would also account for the fact that habituation can even be produced after cerebellectomy (Halstead *et al* 1937)

A tentative block diagram of the circuits we have been studying will be found in Fig 6 According to this schema the reticular formation on hot water habituation increases its impulses to the ipsilateral lateral vestibular nucleus whereby the efferent activity to the peripheral labyrinth is also augmented Via the reciprocal mechanism the activity of the contralateral lateral nucleus is depressed and the depolarization pressure of the labyrinthine sensory cells accordingly increased Subsequent ipsilateral cold water or contralateral hot water habituation on the other hand gradually reduces the activity of the reticular formation on the initially habituated side leading in turn to decreased efferent activity

CONCLUSION

1 A very close reciprocal relationship exists between the two labyrinths

2 Coincident habituation of one labyrinth to both hot and cold water is impracticable

3 Hot water habituation produces in both labyrinths changes of polarity a reversal of which can readily be induced either by ipsilateral cold water or by contralateral hot water habituation both of which activate the same reflex mechanism

4 Habituation disrupts the functional equilibrium of the two labyrinths and the disequilibration may lead to both secondary nystagmus and characteristic dysrhythmia

5 *With caloric tests ad modum Hallpike et al there appears to be no risk* of habituation provided that each succeeding irrigation test elicits nystagmus in the direction opposite to that of the preceding one

ZUSAMMENFASSUNG

An fünf Personen wurde zuerst eine kalorische Untersuchung gemacht Mit wiederholten kalorischen Spülungen mit 44 C wurde danach das rechte Ohr gewöhnt (habituiert) Das Resultat wurde mit einer neuen kalorischen Untersuchung kontrolliert Vier von den Untersuchten wurden schliesslich sekundär am rechten Ohre mit 30 C gewöhnt während statt dessen eine Person mit 44 C im linken Ohre sekundär gewöhnt wurde Das Schlussresultat wurde mit einer finalen kalorischen Untersuchung studiert

Die primare Gewohnung loste eine Nystagmusbereitschaft nach links aus die sekundare dagegen brachte die fruhere Bereitschaft sich zu andern und nach rechts gerichtet zu werden So war der Fall entweder man das rechte Ohr mit kaltem Wasser oder das linke Ohr mit warmem Wasser gewohnte

Man fand ein primar Sekundarnystagmus nach links, aber durch die sekundare Gewohnung schlug er um und wurde statt dessen nach rechts gerichtet Gleichzeitig zeigten die Kurven charakteristische Dysrythmien die sich auch durch die sekundare Gewohnung anderten

Die Ursache der obenbenannten Resultaten glaubt man, gesetztmassige Ver anderungen der Efferentaktivitat der beiden Labyrinthe zu sein

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A HYPOTHESIS CONSIDERING NON-MECHANICAL ASPECTS OF CONDUCTIVE HEARING LOSS[1]

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Evidence is accumulating that conductive lesions of the ear do more than just mechanically impede the sound presented to the cochlea A resolving hypothesis is proposed which appears plausible both from a physiological and a psychological point of view This hypothesis is based on the assumption that deprivation of sound to the cochlea produces, over an extended period of time, a slower replenishment of chemical mediators to the receptor Such a theory could then explain not only the temporary threshold shift pattern at low level exposures but also the various evidences of recruitment in conductively involved ears which may be found in the literature

INTRODUCTION

In recent years it has been assumed that conductive lesions of the auditory mechanism result simply in impedance to the transmission of sound energy to the cochlea (1, 12) Following such a paradigm it was generally considered that at above threshold levels ears with conductive losses behave as do normal ears at comparable sensation levels e g , at 20 db above threshold both the normal and mechanically involved ears will have equal sound pressure presented to the end organ and thus presumably behave in a like manner Although much of the literature would support such a conclusion there have been notable exceptions which would suggest a more complex effect

Fowler's Hobble effect[3] was an early indication that ears with conductive (otosclerotic) lesions did not exhibit the same loudness function as did those with normal conduction mechanisms (5) Nevertheless Fowler (6, 7) later suggested that the Hobble was not highly successful in differentiating otosclerosis from other disorders

More recently Harford & Jerger (9) investigated the effect of the recruitment

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[3] The Hobble effect was felt by Fowler ([illegible]) to be an anomaly in the discrimination of intensity which takes place in certain ears at critical intensities This phenomenon is demonstrated when small changes in loudness appear greater or less than [the changes] to the opposite ear This procedure is carried out through the use of the alternate binaural balance technique

of loudness phenomenon on the delayed speech feedback task Although no actual tests for recruitment were performed the otosclerotic group *(assumed to be a non recruiting group) demonstrated the greatest number* of articulation errors at feedback levels from 0 to 50 db SL The otosclerotics were followed respectively in median number of errors by the labyrinthine hydrops group (presumably a recruiting group) and the masked normal group (also assumed to be recruiting) The other two non recruiting groups the plugged normal and the normal group had the least difficulty in their delayed feedback performance

Harford & Jerger were unable to explain the bizarre behavior of the otosclerotic group nor could they resolve the difference between the otosclerotics and plugged normals on delayed feedback since both respresented conductive lesions

Palva & Ojala (14) noted that the recruitment of loudness phenomenon measured directly by monaural and binaural alternate balancing was found in some of their purely conductive losses (purulent otitis media) Following the removal of the conductive disturbance when identical audiometric procedures were performed the recruitment phenomenon did not appear Recruitment in these instances was not felt to result from any temporary cochlear disturbance

Another area of investigation which offers revealing information regarding the dynamics of conductive lesions has been the study of post stimulatory auditory fatigue Although Hood (11) was not able to differentiate his two otosclerotic subjects from his three normal hearing control subjects when the otosclerotics were fatigued at 43 or 70 db SL and the normals at 80 or 100 db SL Palva (13) using tones of 30 db SL found that he could separate some conductive from sensory neural losses

A study by Epstein & Bower (3) revealed that conductive (otosclerotic) ears demonstrated greater temporary threshold shift (TTS) than the normal hearing noise trauma or presbycusic groups when they were presented with a 20 db SL tone for three minutes In addition the conductives recovered at a slower rate than the normals followed then by the presbycusic and noise trauma groups which demonstrated much faster recovery The results of Epstein & Bower s normal and conductively involved subjects were replicated and confirmed by Epstein Katz & Dickinson (2)

Epstein Katz & Dickinson found that not only did otosclerotic subjects exhibit this surprisingly large amount of TTS and slower recovery but that all types of aural conductive disorders behaved in the same way *They noted* that differences between the various etiological groups vanished when either initial hearing level or duration of hearing loss were taken into account Such findings although remarkable in light of the current concept of mechanical lesions are compatible with the unusual results of Harford & Jerger (9) It would follow that plugged normal ears although presenting almost a 30 db loss in the speech range had a short duration of hearing loss when compared with the otosclerotic group

The evidence appears to point toward a more complex involvement than could be explained by a simple mechanical block alone Hirsh & Bilger (10) found that normal hearing subjects exhibited rapid recovery when stimulated with tones at or above 60 db SL after which there was a slowing down of the recovery process or sometimes a second threshold shift (the bounce) The rapid recovery stage was not evidenced following exposure to a 20 db SL tone and there was greater initial TTS than was observed at 60 db and above

Hirsh & Bilger labeled these two types of recovery patterns R–1 and R 2 The R 1 curve denotes the rapid recovery for the first post exposure minute after which the bounce or a slowing down in recovery rate takes place The R–2 recovery process is slower more stable and is dependent upon the sensation level and duration of the stimulating tone This pattern is most clearly seen at exposure levels below that needed for R 1

Hirsh & Bilger state

> It is tempting of course to identify these two processes with certain structures in the auditory system Slow recovery processes suggest recovery from depletion of chemical materials but this does not afford a real distinction between nerve and receptor cells We might guess that R 1 has to do with the excitability of nerve fibers and that R 2 has to do with the chemical properties of receptor cells but the evidence allows us no more than a guess It seems reasonable to suppose however that we need not look for central mechanisms because similar recoveries from acoustic stimulation with sensitization for nerve action potentials measured at the round window of the cat have been reported Furthermore these physiological changes occur at the same times as those reported here We look forward to the possibility of identifying and dissociating R 1 and R 2 either by electrophysiological or clinical techniques (10 p 1194)

A Resolving Hypothesis

When the R 1 and R 2 concepts are brought to bear on the findings of Epstein & Bower they generate some explanations and additional inferences which in turn may be applied to the data of Epstein Katz & Dickinson Epstein & Bower found as did Hirsh & Bilger that at 20 db SL normal hearing subjects demonstrated a moderate temporary threshold shift with a slow recovery rate A recovery pattern of this nature would fit the R 2 concept This could assume then if Hirsh & Bilger are correct in suggesting chemical depletion that the gradual recovery takes place as the chemical supply is slowly replenished to the receptor cells

Both of Epstein & Bower's sensory neural groups demonstrated less fatigue and a more rapid recovery rate over the first and succeeding minutes than did the normal or otosclerotic groups For example if a subject with a cochlear disorder and a subsequent hearing loss of 40 db were exposed to a 20 db SL tone this would represent energy of approximately 60 db above normal threshold entering the cochlea One would expect a resultant R 1

recovery which is similar to the pattern of recovery for normal ears at 60 db (10) The same would logically be true for other sensory neural losses and this too is apparent from their data

When 20 db SL was presented to Epstein & Bower s conductive (otosclerotic) subjects who might for example have also had a loss of 40 db only 20 db of the stimulus energy would be provided to the cochlea assuming the integrity of the conductive block In order to explain the greater than normal shift and the relative absence of any rapid recovery in the first minute following stimulation primarily in the higher frequencies (2 3) the following speculation may be considered

Accepting the concept so cautiously set forth by Hirsh & Bilger one might conclude that conductively involved ears are more sensitive to low level stimulation because their receptor cells have a minimum of chemical reserve It may be that with a mechanical block in the conductive mechanism the end organ receives less stimulation from daily ambient noise exposure This would be especially true for the high frequencies which are less plentiful and also less powerful in our environment and are more effectively attenuated by the temporal bone surrounding the aural end organ It would not be unreasonable in light of the homeostatic processes of the body to suppose that such a factor of apparent disuse over a prolonged period of time may encourage a slowing down of the production of chemical mediators involved in sound reception Thus the conductive ear with a moderate or severe loss of long duration may ultimately become less efficient in replenishing the chemical mediator for the receptor cells when it is depleted by a controlled continuous stimulus

Although the hypothesis which has been proposed above is highly tenuous it nevertheless follows the model of chemical processes in the central nervous system (8) and could serve to explain the bizarre findings of Epstein & Bower

In applying the implications of a chemical deprivation hypothesis to the results of Epstein Katz & Dickinson no serious contra indications are apparent If the hypothesis is correct one might expect that individuals with mild losses would behave more normally than individuals with severe losses because of more nearly normal chemical activity The findings bear this out that is the Serous Otitis Media group with the mildest loss of hearing behaved most like the Normal group The same would be true for the duration variable The longer the period of hearing loss the more pronounced the R 2 pattern the stable fatigue trace which the conductives demonstrated It follows that the high frequencies are proportionately least available in the cochlea of an ear with a mechanical block and thus the restricted reservoir of the chemical mediator This could result in a threshold shift and recovery rate resembling Hirsh & Bilger s R 2 recovery pattern

Epstein & Shubert s (4) findings of overlaid per stimulatory fatigue may explain the lack of recovery over time which was noted in Epstein & Bower s conductive group and replicated in the investigation of Epstein Katz &

Dickinson Indeed further fatigue as noted particularly in Epstein Katz & Dickinson s Miscellaneous and Otosclerotic groups could be resolved on the basis of depleted chemical supply and overlaid per stimulatory fatigue

Some factors if left to vary would create wide deviations in otherwise similar conductive ears The amount of individual aural stimulation would vary with circumstances involving exposure to high level noise and use of amplification (hearing aids) Conductive losses with such stimulation should then behave more normally than similar losses without this exposure

DISCUSSION

In order to rule out the middle ear mechanism *per se* as the cause of the unusual behavior of conductively involved ears summarized herein two simple clinical methods suggested themselves (in addition to many others) First it was reasoned that if Harford and Jerger s plugged normal group performed only on a par with the normal group and if wide differences were found between true conductives (otosclerotics) and artificially plugged normals the primary variable would be related to the duration of the hearing loss Thus these same factors could be evaluated through employment of the low level post stimulatory fatigue test Secondly we would expect that once a conductive lesion of long standing is eliminated the response to low level exposure would not suddenly resemble the normal pattern if ever (15) Otosclerotics tested prior to and following successful stapes mobilization would provide such an opportunity

Data collected to date tend to suggest that normal ears unplugged and plugged behave in essentially the same fashion This suggests that merely producing a mechanical impedance to sound is not sufficient to produce the LTS pattern summarized herein These results may be due either to the factor of duration of hearing loss as we are proposing or due to the fact that the artificial lesion is being produced in the external canal and not as the true losses in the middle ear

The information based on preliminary data on seven otosclerotic subjects indicates that the performance before and after successful stapes mobilization surgery is not significantly different even when evaluated as long as six weeks after the operation It should be noted that any effects of trauma due to surgery would tend to produce even more rapid recovery than the normal ear The fact that this did not occur even though hearing was returned to a level within the normal range is striking This gives further support to the notion that the observed conductive loss phenomenon operates even with a normal ized mechanism provided that it follows a long period of hearing loss It would be difficult to refer such findings to the middle ear mechanism This would be especially convincing if upon retest after one year or more normal responses are found on tests of low level post stimulatory fatigue or even the delayed speech feedback task

The need for additional experimental work to further resolve the specific

behavior of the auditory system responsible for this phenomenon is obvious It appears as though the ultimate resolution of the non mechanical effects of conductive lesions whether actually chemical deprivation or other, will await physiological verification

ZUSAMMENFASSUNG

Es häufen sich die Indizien dass Verletzungen der Schalleitungsorgane im Ohr weitergehende Folgen haben als die rein mechanische Behinderung des Schalles, welcher der Cochlea zugeleitet wird Es wird eine Lösungshypothese vorgeschlagen die sowohl vom physiologischen als auch vom psychologischen Standpunkt aus annehmbar erscheint Diese Hypothese gründet sich auf die Vermutung dass eine Unterbindung der Schallzuleitung zur Cochlea für längere Zeit einen langsameren Nachschub an chemischen Mittlern zum Rezeptor zur Folge hat Eine derartige Theorie könnte dann nicht nur das Bild zeitweiliger Schwellenverschiebung bei schwachen Reizungen erklären sondern auch die verschiedenen Anzeichen von Reflexunahme in leitungsgestörten Ohren wie man sie in der einschlägigen Literatur findet

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COCHLEAR AND VESTIBULAR DISTURBANCES AFTER STAPEDIOLYSIS

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The post operative course after stapediolysis was followed by means of positional nystagmography and bone conduction audiograms In 70 per cent it was possible to demonstrate positional nystagmus A decrease was shown to take place for the frequency of 4000 Hz this decrease was of distinctly longer duration in cases with positional nystagmus These signs of labyrinthine irritation have as a rule, disappeared after one week After six weeks the bone conduction value for 4000 Hz rose, on an average, by 6 db, which clearly demonstrates that the surgical technique applied (according to Frenckner Holmgren) caused only a transient labyrinthine effect

Every operation on the stapedial plate involves an opening of the perilymphatic space, with a more or less pronounced escape of perilymph which may be assumed to be followed by a labyrinthine reaction As a rule however more detailed data on these reactions are not given in the accounts of various forms of stapediolysis Consequently an investigation was started in 1959 at the Department of Otolaryngology of the Sodersjukhuset into functional disturbances of the labyrinth immediately after stapediolysis

The vestibular disturbances were analyzed by Bergstrom and Ivstam who showed that in about two thirds of all cases labyrinthine reaction occurred which as a rule subsided within one week The post operative reaction in the labyrinth was explained as an aseptic labyrinthitis The author has followed the cochlear as well as the vestibular disturbances in a series of patients during the years 1960 and 1961

Material

After excluding all patients where pre operative vestibular disturbances could be demonstrated the investigation comprised 64 cases of which 50 were females and 14 males between the ages of 26 and 67 years Stapedial fixation was verified in each case during operation

Method of Investigation

The vestibular functions were followed by means of positional tests using electronystagmography (according to Preber 1958) Preliminary tests had

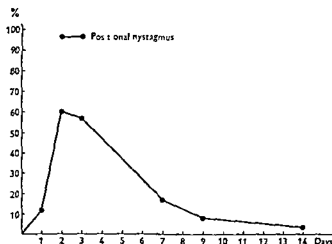


Fig. 1. Results of positional tests. Number of patients with positional nystagmus during the first two weeks after operation.

shown that this method is more sensitive than cupulometry. The positional tests were carried out (1) the day before the operation, (2) on the day of the operation (4–6 hours after operation), and subsequently (3) daily (excepting at weekends) during the first week until the reaction became normal. Practically speaking, they never caused the patients discomfort.

Hearing was followed by the aid of bone conduction audiograms for frequencies of 250, 500, 1000, 2000, 3000 and 4000 Hz.

Operative Technique

Mobilization of the stapes was effected according to the principles described by Frenckner & Holmgren (1957). In all the cases the stapedial plate was fractured, which was followed by a more or less pronounced escape of perilymph. In almost every case an anterior crurotomy was also performed.

Prophylactic administration of penicillin and sulfa was started on the day before the operation and continued during the whole period of hospitalization (approximately one week).

Results

A. Vestibular function

The results of the positional tests are given in Fig. 1. On the day of operation (4–6 hours after operation) eight patients or 13 per cent showed positive tests, whereas on the following day there were not less than 38 patients or 60 per cent, and on the third day 36 patients or 56 per cent. Subsequently, the number decreased rapidly and on the ninth day only five, or 8 per cent, had positive tests. These five patients had positional nystagmus for 11 days, two, two, three and four weeks respectively. They reported also subjective dizziness persisting more than one week. In all 45 patients or 70 per cent had positional nystagmus at some time, some of them had it only once.

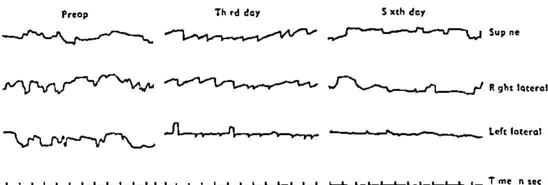


Fig. 2. Postural test in case 5136/59. No nystagmus was present pre-operatively. Left beating nystagmus was recorded in supine and right lateral positions on the third post-operative day. After six days the positional test results were again normal (Bergstrom & Ivstam 1960).

and then always on the first, second or third day. In the majority of cases, however, nystagmus persisted two to three days.

Analysis of the nystagmus curves shows that in all cases except three nystagmus was directed *towards* the operated ear (Fig. 2). The exceptions were two cases with nystagmus *from* the operated ear and one case with direction changing nystagmus. In these three cases nystagmus could be shown at one examination only. In six cases out of 10 with a nystagmus lasting more than six days, this developed into direction changing nystagmus. Thus, in all 93 per cent or 42 patients out of 45 with positive tests had direction determined nystagmus (in accordance with Nylen's type II) which in six cases, however, developed into direction changing nystagmus.

No correlation could be shown to exist between operative trauma and the subsequent escape of perilymph and the frequency of positive positional tests.

B. Hearing function

Analysis of the bone conduction audiograms does not show any definite tendency towards change in respect of frequencies under 4000 Hz. For the frequency 4000 Hz, however, there is a definite post-operative change. This is shown in Fig. 3. Here the pre-operative bone conduction value has been given as 0. In the groups with positive and negative positional tests respectively the mean change in the frequency 4000 Hz is given. On the day after operation a decrease of 7 and 4 db respectively was observed. In the group with negative positional tests, already on the following day, practically the same values were found as existed pre-operationally.

In the group with positional nystagmus, bone conduction was still further reduced and showed a maximum decrease of 11 db after three days. It gradually reverted to pre-operative level but only after more than a week. After six weeks the bone conduction value for 4000 Hz rose by about 6 db.

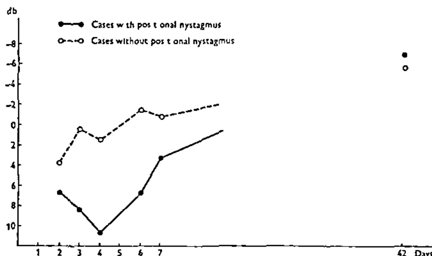


Fig 3 Bone conduction after stapediolysis Frequency 4000 Hz Pre operative level 0 db

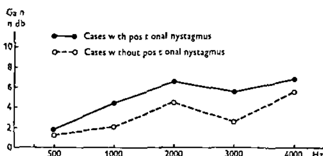


Fig 4 Improvement of bone conduction six weeks after stapediolysis

above pre operative level for both groups In no case was there any decrease in bone conduction exceeding 5 db The average increase in bone conduction for frequencies 500 4000 Hz was after six weeks 3 3 db for the group with negative positional tests and 5 0 for the group with positive positional tests

The improvement in the bone conduction for frequencies of 500 1000 2000 3000 and 4000 Hz is shown in Fig 4

DISCUSSION

Shambaugh & Takahara have shown that fenestration gives rise to mild labyrinthitis in 48 per cent In connection with experimental operation on animals—fenestration (Shambaugh & Takahara) and fracturing of the stapedial plate (Altman & Basek)—histologic changes were found of a type that was termed serous labyrinthitis in 86 and 45 per cent of the cases respectively In the disease termed labyrinthitis serosa cum nystagmocephalo

statico (Nylen) the same histologic picture is observed with hyperemia and edema principally in the saccule and utricle as well as in the basal coil of the cochlea The clinical picture is characterized by nystagmus which as a rule is directed *from* the healthy ear or is direction changing and by more or less pronounced neurogenous impairment of hearing The findings of this investigation agree well with this Indeed impairment of hearing could be shown to take place only for 4000 Hz this frequency however is usually the first to be affected by traumatic injuries The localization of the histologic changes in the cochlea probably also first influences the highest frequencies

Consequently there is reason to assume that some hours after a stapediolysis a labyrinthine reaction occurs with hyperemia and edema localized mainly in the parts closest to the oval window the utricle saccule and basal parts of the cochlea and to some extent the semicircular canals

This reaction gives rise to a reversible functional effect on both the cochlear and vestibular regions of the labyrinth

Even in those cases where no positional nystagmus could be registered on the day after the operation a decrease in the frequency of 4000 Hz was observed This can be due either to the cochlea being more sensitive than the vestibular apparatus or to the fact that we can more readily demonstrate a cochlear than a vestibular disturbance

After six weeks the bone conduction value for 4000 Hz improved on an average by 6 7 db and in no case was it reduced by more than 5 db This clearly shows that the technique used for stapediolysis does not cause any permanent damage to the labyrinth Moreover improvement in the bone conduction curve for 500 4000 Hz (Fig 4) indicates that the technique has also in general brought about a mobilization of the stapedial plate

ZUSAMMENFASSUNG

Der nachoperative Verlauf nach Stapediolyse wurde bei 64 Fallen mit Hilfe von Lagenystagmographie und Knochenleitungsaudiogramm nachgeprüft Bei 70 % der Falle gelang es Lagenystagmus nachzuweisen Fur die Frequenz 4000 Hertz konnte eine vorubergehende Senkung festgestellt werden Diese war bei Fallen mit Lagenystagmus deutlicher und von langerer Dauer Diese Anzeichen von Labyrinthreizung sind in der Regel nach einer Woche verschwunden Nach 6 Wochen sind die Knochenleitungswerte fur 4000 Hertz im Durchschnitt um 6 db gestiegen was klar zeigt dass die verwendete chirurgische Technik (nach Frenckner Holmgren) nur eine vorubergehende Labyrinthreizung zur Folge hatte

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ZUR HISTOLOGIE DER PAUKENSKLEROSE

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Beschreibung der Charakteristika eines Falles von Paukensklerose, wobei auf einer intakten Steigbügelfussplatte noch Stapesreste in einem die ovale Fensternische völlig einnehmenden und verknocherten Gewebsblock gefunden wurden.

Die Paukensklerose ist erst seit der Jahrhundertwende ein wohlumrissener Begriff, da vordem die heute als Otosklerose bekannte Erkrankung der Labyrinthkapsel hinzugezählt wurde. Dieses mag seine Ursache darin gehabt haben, dass beide Krankheitsbilder mit einer vorwiegend am Schalleitungsapparat lokalisierten Störung einhergehen. Während bei der Otosklerose — nun unter Weglassung histologischer Kriterien — das Trommelfell fast immer im Rahmen der Norm gefunden wird, nimmt die Paukensklerose jenes breite Feld von hypertrophen Narben bis zu Verknöcherungen am Schalleitungsmechanismus ein, vom intakten Trommelfell mit eingelagerten Kalkplatten bis zum Endzustand nach chronischer Mittelohreiterung.

Es ist in diesem Zusammenhang nicht uninteressant, sich durch eine kleine historische Rückschau die Entwicklung aller jener Erkenntnisse, welche zur Trennung von Otosklerose und sklerotischen Residuen in der Pauke geführt haben, zu vergegenwärtigen. 1873 beschrieb v. Troltsch ausgedehnte Hyalinisierungen im Tympanonbereich, wobei das Bindegewebe durch sekundäre Verkalkungen im Sinne regressiver Metamorphosen letztlich Knochenstruktur annehmen kann. Politzer (1893) sah den folgenschwersten Ausgang einer chronischen Mittelohrentzündung im Hinblick auf das Hörvermögen in der Ankylose des Steigbügels mit dem ovalen Fenster und wies darauf hin, dass bereits G. B. Morgagni solches erkannt und beschrieben hatte. Diese Blockade der Schalleitung wurde durch Produkte einer interstitiellen Entzündungsform der Mittelohrschleimhaut (Sklerose) bedingt. Auch Katz (1901) trennte die heutige Otosklerose noch nicht von Residuen nach abgelaufenen Entzündungen und Habermann (1904) fand bei manchen chronischen Otitiden reaktive Knochenneubildung neben noch bestehenden Entzündungserscheinungen, im histologischen Schnitt imponierten alle Stadien der Otitis dann nebeneinander. Brühl (1905) sah in den von ihm beobachteten fibrösen Umwandlungen der Mittelohrschleimhaut mit Atrophie, Verkalkung und Verknocherung eine Teilerschinung des „Catarrhus auris media chronicus". Erst nach Politzer's klassischer Publikation über die Otosklerose und Erkennung ihres Wesens schlug Manasse 1917 aus Gründen besseren Verstandnisses um das Geschehen die Bezeichnung „Ostitis chronica metaplastica der Labyrinthkapsel" für diese primäre, höchstwahrscheinlich nicht auf banal entzündlicher

Grundlage beruhende Erkrankung vor. Die nach entzündlichen Prozessen auftretenden Veränderungen spielen sich nämlich hauptsächlich in den subepithelialen Gewebsschichten ab, wobei metaplastischer Knochen direkt aus Bindegewebe entstehen kann. Der später von Brühl vorgeschlagene Terminus „Otosklerose" wurde letztlich beibehalten und 1926 wies der Autor nun im Zuge der neugewonnenen Erkenntnisse auf die Notwendigkeit einer scharfen Trennung zwischen otosklerotischer Stapesankylose und einer solchen durch Folgezustände chronischer Mittelohrkatarrhe hin.

Man sieht, dass es fast 50 Jahre gedauert hat, bis die beiden erwähnten Mittelohraffektionen mit konsekutiver Schalleitungsstörung wesensmässig genau bekannt waren und entsprechend eingeordnet werden konnten. Aus jüngster Zeit (1955) liegt ein zusammenfassendes Referat von Zöllner & Beck vor, welches allen wissenswerten Details Rechnung trägt.

Der sklerosierende Vorgang in der Pauke beginnt oft schon in der Kindheit und führt später in den meisten Fällen zu einer Blockierung des ovalen Fensters, wobei die Ossikula manchmal schalenartig mit Kalk überzogen sind. Bei ruhendem Prozess ist die Schleimhautauskleidung des Tympanons elfenbeinfarben und glatt. Die Nische zum Vorhoffenster kann zuckergussartig ausgefüllt sein und mitunter ragt nur das Stapesköpfchen heraus. Da die Affektion in keiner Weise mit dem Labyrinthknochen im anatomischen Sinn zusammenhängt — sie entsteht auf narbiger Grundlage im Schleimhautbereich des Mittelohres — findet man stets eine dünne bindegewebige Trennschichte zwischen Labyrinth und verkalkten bzw. verknöcherten Arealen. Es wurde vieles als Adhäsivprozess oder Residuum nach chronischer Mittelohreiterung bezeichnet, was eigentlich schon der Paukensklerose zuzuordnen ist (Zöllner). Entzündliche Exostosen hingegen sind trotz des polymorphen Bildes selten zu finden (Maspétiol). Histologisch geht eine allfällige Knochenbildung direkt vom Bindegewebe aus und man findet reichlich hyalinisierte Stränge neben lockerer zelliger Infiltration chronisch entzündlichen Charakters. Es sind auch Dekalzifizierungsprozesse an Hammer und Amboss beschrieben worden (Merlo & Sillingardi).

Um einen eigenen Beitrag zu diesem Ossifikationsvorgang im Mittelohr leisten zu können, soll nach auszugsweiser Wiedergabe von Krankengeschichte und Operationsbefund einer Patientin der Klinik Novotny in Wien das feingewebliche Bild der so mannigfaltig in Erscheinung tretenden Paukensklerose an Hand vorliegender Beobachtungen im speziellen besprochen werden.

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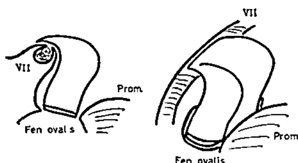


Abb 1

ist beträchtlich sekundär ausgeweitet und zeigt eine regelmässige jedoch stellenweise etwas unscharfe Begrenzung desgleichen der Aditus ad antrum Tegmen und knöcherne Sinusschale sind nicht nachweisbar verändert Es handelt sich demnach um ein Antrumcholesteatom das möglicherweise akut exazerbiert ist — Bei der Radikaloperation des rechten Ohres findet sich neben einem kariösen Hammerrest und dem klinisch und röntgenologisch aufgedeckten Cholesteatom die Gegend des Vorhoffensters durch ein grosses elfenbeinfarbenes knochenhartes Gebilde ausgefüllt welches das Niveau des Promontoriums überragt und den Falloppischen Kanal in einer Breite von etwa 3 mm lippenartig überdacht (Abb 1)

Dieses Gebilde ist *nur ganz gering* mobil und nach seiner Luxation sieht man in das eröffnete ovale Fenster sowie auf den etwa 2 mm freiliegenden N facialis welcher blaurot verfärbt jedoch nicht gequollen erscheint Die Fenestra vestibuli wird vorläufig durch Spongostan später durch ein Kutistransplantat abgedeckt und die Operationshöhle derart ausgekleidet dass eine kleine Pauke (Tympanoplastik IV) resultiert Bei der Operation gelangt etwas Blut ins Vestibulum

Am 3 postoperativen Tag sind Erbrechen und verlängerter I gradiger Nystagmus nach beiden Seiten geschwunden Schwindelgefühl wird bis zum 7 Tag vermerkt 2 Wochen nach der Operation ist das Hörvermögen für Flüstersprache von 60 cm auf ad concham und für Konversationssprache von 4 m auf ½ m abgesunken Tonaudiometrisch ist der Hörverlust im Sprachbereich noch im Rahmen der Fehlerquelle ab 3000 Hz findet sich jedoch eine beträchtliche Senke für die Luftleitung die Knochenleitung zeigt in diesem Bereich ebenfalls einen Abfall um ca 10–15 db Anlässlich einer Kontrolluntersuchung 2 Jahre nach der Operation ist das Ohr trocken der audiometrische Hörabfall ist teilweise aufgehoben auch die Knochenleitung hat sich geringfügig erholt die Werte der Sprachprüfung sind allerdings gleich geblieben Es bestehen keinerlei subjektive Beschwerden

Es konnte in dem vorliegenden Fall zwar eine Sanation jedoch keine Restauration des erkrankten Ohres erzielt werden im Gegenteil das Hörvermögen ist postoperationem deutlich schlechter geworden und geblieben

Die histologische Untersuchung des knöchernen Blockes aus der ovalen Fenster region ergibt Intakte Fussplatte mit knorpeliger vestibulärer und knöcherner tympanaler Schichte Im Zentrum der bds kolbig aufgetriebenen Fussplattenränder ein arterielles Gefäss quer getroffen Über der Basis stapedis reichlich fibrilläres u verkalktes Bindegewebe ohne Struktur sog sklerosiertes Bindegewebe Darin vereinzelte Areale von Faserknochen welcher grösstenteils der Nekrose anheim ge

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Form eine Kippbewegung gewährleistet und ausserdem die Auflagefläche für die zum Paukenabschluss verwendete Kutis genügend gross.

Beim Versuch, den knöchernen Block ausreichend beweglich zu machen (siehe Operationsbefund), ist dieser plötzlich zum Corpus liberum geworden und da das Labyrinth nun einmal eröffnet war, erfolgte seine Eliminierung. Die Klinik Novotny steht auf dem sicher berechtigten Standpunkt, bei allen entzündlichen Affektionen an den Fenstern möglichst schonend zu arbeiten und selbst mit der Vornahme einer Fensterprobe nicht allzu freizügig zu sein, auf jeden Fall aber eine Eröffnung des Vestibulums strikte zu vermeiden. Bozzi und Invernizzi (1956) hingegen beschrieben 3 Fälle von Tympanoplastiken, bei denen entweder das runde oder das ovale Fenster eröffnet wurden und wobei keine Labyrinthitis und keine nennenswerte funktionelle Störung in der Folge eingetreten seien; vielleicht wurde diese Ansicht seither ebenfalls revidiert. Audiometrisch ist in dem hier beschriebenen Fall die zum Teil nur passagere Abnahme des Hörvermögens speziell für hohe Töne insoferne charakteristisch, dass als Ort der hauptsächlichen Schädigung durch die Labyrintheröffnung die dem ovalen Fenster benachbarte Schneckenbasis bezüglich Transmission und Perzeption (?) anzusprechen ist.

Die Schwindelerscheinungen labyrinthären Charakters sind hier wohl als im Rahmen der akuten Exazerbation des Cholesteatoms aufzufassen, da intra operationem keine Fistel im horizontalen Bogengang gefunden werden konnte. Allerdings kann man vestibuläre Ausfalls- oder Reizerscheinungen geringen Grades nach van Caneghem auch bei Adhäsivprozessen und Tympanosklerosen beobachten. Der Autor nimmt an, dass der sklerosierende Vorgang nicht in der Pauke allein Halt mache und die Labyrinthsymptomatik dann durch trophische Störungen der sensorischen Elemente infolge Verringerung des endolabyrinthären Druckes hervorgerufen werden könne.

Die vorliegende Publikation soll nicht Problemen einer bestimmten Operationssituation und deren Folgeerscheinungen Rechnung tragen, sondern einzig das makro- und mikroskopische Bild einer fortgeschrittenen Paukensklerose (hier mit Cholesteatom) den bisher beschriebenen Erscheinungsformen ergänzend hinzufügen.

SUMMARY

The author describes the features of a case of tympanic sclerosis, in which on an intact footplate vestiges of the stapes were still found in an ossified tissue block fully occupying the oval window recess.

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ÜBER DIE SEITLICHE NASENSPALTE

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Die seitliche Nasenspalte ist eine sehr seltene Missbildung. Auf Grund eigener Fälle und nach kritischer Sichtung der in der Literatur beschriebenen Fälle gelangen wir zur Folgerung, dass diese Nasendefekte sekundär entstehen. Das Primäre ist eine Schädigung des Gehirns oder der Schädelkapsel. In jedem Fall konnte irgendeine „Geschwulst" gefunden werden. Ein Teil dieser Geschwülste „heilte" intrauterin. Der Kliniker sieht oft solche Erscheinungen, die auf eine intrauterine Regenerationsfähigkeit des Keimlings hinweisen. Auch in den hier angeführten Fällen konnten wir intrauterine Regeneration feststellen. Mit den hier vorgetragenen Auseinandersetzungen soll bewiesen werden, dass die klinische Erfahrung und Beobachtung auf einige embryologische und pathobiologische Erscheinungen Aufschluss geben kann. Dies mahnt aber den Kliniker, die Missbildungen nicht nur vom therapeutischen Standpunkt aus zu betrachten, sondern es ist seine Pflicht, die Missbildung der einzelnen Organe in seinen Verbindungen und Zusammenhängen mit den benachbarten Organen und Organsysteme zu untersuchen. Auch die kleinsten Abweichungen vom Normalen können Hinweise auf nicht sichtbare, aber eventuell diagnostizierbare Defekte liefern.

Die seitliche Nasenspalte ist eine seltene Missbildung. In der gesamten Spezialliteratur seit den ältesten Zeiten sind nur einzelne Fälle beschrieben worden, die aber nicht alle als seitliche Nasenspalten angesehen werden können. Es wurden auch solche Fälle als seitliche Nasenspalten angegeben, die eigentlich grosse, breite Lippen-Gaumenspalten oder aber seitliche Gesichtsspalten waren. In der älteren Literatur wurde die mediane Nasenspalte oder die einseitige Rüsselbildung der Nase ebenfalls als seitliche Nasenspalte bezeichnet. Heute verstehen wir unter seitlichen Nasenspalten nur jene Veränderungen, wo der Nasenflügel oder die seitliche Nasenwand irgendwie gespaltet ist. Wenn wir die in der Literatur erwähnten Fälle, die tatsächlich seitliche Nasenspalten waren, mit unseren Fällen ergänzen, so sehen wir eine Reihe verschiedener Variationsformen, aus welchen wir sowohl auf die Embryologie wie auf die formale Genese der Entstehung dieser Missbildung einige Schlüsse ziehen können.

Das Problem ist deswegen besonders bemerkenswert, weil embryologisch die Nase seitlich keine Spalte hat, also kann sie nicht im Sinne der älteren

Morphogenetiker als Hemmungsbildung angesehen werden. Sie ist, wie es einige Autoren beschreiben und wie wir es mit unseren Fällen zu beweisen versuchen werden, eine selbständig entstandene Deformität. Kritisch betrachtet sind nur sehr wenig echte seitliche Nasenspalten beschrieben worden, in der Zahl etwa 20 Fälle. Sicherlich sind viel mehr zur Welt gekommen, aber teils war der Defekt so kleingradig, dass man ihm keine besondere Beachtung schenkte, teils haben sich die Beobachter keine Mühe genommen, die Fälle zu publizieren. Da wir nur von jenen Fällen sprechen können, die in der Literatur aufzufinden sind, steht uns nur eine kleine Zahl zur Verfügung, aus welcher wir nur eine grobe Durchschnittsstatistik über das Vorkommen dieser Missbildung zusammenstellen können. Unserer Meinung nach kommen diese Deformationen viel öfter vor, doch ist der eigentliche Defekt verborgen und nur bei genauer Untersuchung feststellbar. Vom morphogenetischen Standpunkt aus ist es gleichgültig, ob der Defekt klein oder gross ist. Wenn wir uns eine Vorstellung vom Entstehen dieser Missbildung machen wollen, so müssen wir die verschiedenen Variationsformen nebeneinander stellen, denn nur so sehen wir die Entwicklung vom kleinsten Defekt bis zur grössten Entstellung.

Wir Kliniker müssen bei der Untersuchung der Missbildungen genau so vorgehen, wie der Embryologe, der aus den einzelnen Entwicklungsstadien die gesamte Embryonalentwicklung aufstellt. Der Embryologe sieht nie eine fortlaufende Entwicklung an menschlichen Keimlingen und er kann nie beobachten, wie sich der Embryo entwickelt hätte, wenn er am Leben geblieben wäre. Der Embryologe hat ein totes morphologisches Material und aus den vielen einzelnen Fällen, aus den verschiedenen Entwicklungsstadien stellt er das System der Normalentwicklung auf.

Bei der pathologischen Entwicklung versagt aber oft die normal embryologische Morphologie. Deswegen ist es unsere Pflicht, auch das klinische Missbildungsmaterial so zu ordnen, wie es der Embryologe tut und von den verschiedenen Variationsformen eine solche Reihe aufzustellen, wovon wir die pathologische Entwicklung erklären können. Dazu sind die seltenen Missbildungen besonders geeignet, denn sie können einige Probleme klären, die *der Embryologe nicht zu Gesicht bekommt und sich manchmal nicht einmal* vorstellen kann. Mit diesen Fällen können wir dem Embryologen behilflich sein.

In diesem Sinne möchte ich einige Nasenmissbildungen aus meiner speziellen chirurgischen Abteilung für angeborene Missbildungen vorführen. Diese sollen nicht kasuistische Ergänzungen zu den bisherigen in der Literatur beschriebenen Fällen darstellen, ich möchte im Gegenteil mit den kasuistisch beschriebenen Fällen versuchen, eine Erklärung zu finden, wie diese sonderbare Missbildung entstanden sein möchte. Gleichzeitig möchte ich darauf hinweisen, dass wir bei der Untersuchung einer Missbildung auf alle Einzelheiten aufmerksam sein müssen, wenn wir den *Embryologen* und den Morphologen behilflich sein und wenn wir eine klinische Embryopathologie ausüben wollen, wie ich es in meinen Aufsätzen. Die theoretische



Abb. 1



Abb. 2

Abb. 1. Spalte am linken Nasenflügel.

Abb. 2. Narbe auf der Stirn. Unterhalb der Narbe ist noch ein Rest des Tumors sichtbar.

Grundlage einer klinisch-chirurgischen Embryopathologie (Ztbl. f. Chir.) und Die klinische Embryopathologie (Dtsch. Gesundheitswesen) erörtert habe.

Die morphologisch sichtbaren einfachsten Entstellungen sind jene, die Trendelenburg (1886) als „intrauterin verheilt" bezeichnet, die ich aber eher eine „intrauterine Regeneration" nenne. Grünberg (1910) erwähnt die Lehrsche Beobachtung einer solchen intrauterin geheilten Nasenspalte. Es soll sich hier um eine angeborene Fibrombildung des Nasenflügels handeln, die teils geheilt war und eine Narbe zurückliess. Ruttin beobachtete an einem 7jährigen Knaben ein Fibrom am Nasenflügel. Stupka (1938) sagt, dass Fibrome und Cavernome im Bereiche fetaler Spalten nicht selten vorkommen. Diese Feststellung können wir aus unserem Material bestätigen mit dem Zusatz, dass nicht nur Fibrome und Cavernome, sondern auch andersartige Tumoren, wie z. B. Meningocelen und Dermoide, Spaltungen verursachen können.

Madelung (1888) und auch Lexer (1913) beschreiben Fälle, wo am Nasenflügel ein dreieckiger Defekt zu sehen war, welcher durch den knorpeligen Nasenflügel ging. Im Jahre 1888, als Madelung seine Beobachtung bekannt gab, existierte noch keine Röntgenuntersuchung; auch in der Lexerschen Kasuistik lesen wir nicht, ob bei der seitlichen Nasenspalte Röntgenaufnahmen gemacht worden sind. So bleiben beide Fälle nur seltene kasuistische Kuriosa, ohne nähere Entstehungsursachen finden zu können. Wenn wir Stupkas Feststellung annehmen, wonach Tumoren imstande sind, Spaltungen hervorzurufen, dann können wir die Fälle von Madelung und Lexer als Reste intrauterin verheilter Tumoren ansehen. Wie erwähnt, hat uns auf diese Möglichkeit Trendelenburg aufmerksam gemacht.

Hier können wir unseren ersten Fall einreihen, den wir in den Bildern 1—3 vorstellen. Wir sehen ein 18 Monate altes Kind, an dessen linkem Nasenflügel

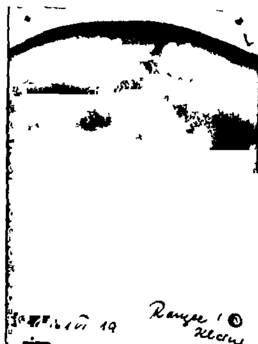


Abb. 3



Abb. 4

Abb. 3. Am Röntgenbild ist ein Knochendefekt am Stirnbein zu sehen.

Abb. 4. Meningocyste auf der linken Seite des Nasenrückens.

eine zweizackige Spalte zu beobachten ist. An der Stirne (Abb. 2) befindet sich eine Narbe, unterhalb der Narbe ein weiches tumorartiges Gebilde. Das Kind hat einen kleingradigen Hypertelorismus, ist aber sonst geistig und körperlich vollständig normal. Die Eltern erzählten, das Kind sei mit einer grossen Geschwulst an der Stirn zur Welt gekommen, welche in einem Provinzkrankenhaus operiert wurde. Es hat aber eine so starke Blutung eingesetzt, dass der ganze Tumor nicht entfernt werden konnte und die Operation dringendst beendet werden musste. Den Rest des Tumors konnten wir noch unterhalb der Narbe sehen. Leider wurde das exstirpierte Stück histologisch nicht untersucht, doch ist es sicher eine Meningocele gewesen. Eine weitere Operation zur Entfernung des zurückgebliebenen Tumors habe ich auf eine spätere Zeit verschoben, da kein Grund vorlag, den Eingriff jetzt zu machen. Bei der Röntgenaufnahme stellte es sich heraus, dass am Schädel ein pfennig grosser Knochendefekt vorhanden ist. Damit sahen wir bestätigt, dass der angeborene Tumor der Stirn mit dem Gehirn bzw. mit dessen Entwicklung im Zusammenhang steht. Die recht zeitige normale Entwicklung des Nasenflügels wurde durch den Tumor gehindert. Durch die intrauterine Regenerationsfähigkeit hat sich der Tumor mehr oder weniger vom Gehirn abgesondert oder abgeschnürt und das Gehirn entwickelte sich anscheinend normal. Wir können aber nur nach den neurologischen und psychologischen Untersuchungen feststellen, ob die Gehirnentwicklung tatsächlich normal ist.

Aus diesem einen Fall können wir noch keine Schlüsse ziehen. Die hier soeben beschriebenen sichtbaren Tatsachen sind nur mit Hypothesen erklärt worden und wir müssen diese Hypothesen irgendwie beweisen. Experimentell ist es nicht möglich, dieselbe Missbildung zu erzeugen. Da meines Wissens Nasenflügelspalten bei Tieren nicht vorkommen, können uns Tierexperimente keine Beweise liefern. So bleibt uns nur eine Möglichkeit, die vergleichende Untersuchung ähnlicher Fälle.

Kredel (1898) beschreibt einen Fall, wo der linke Nasenflügel genau in seiner Mitte durch eine strichförmige Furche tief eingeschnitten ist, welche am freien Rande des Nasenflügels beginnt, bis zur knöchernen Nase reicht und eine schräge Richtung hat. Diese Furche, die nach Trendelenburg als intrauterine Heilung angesehen wird, muss durch irgendwelchen pathologischen Prozess entstanden sein, denn die Heilung kann nur die Folge eines pathologischen oder abnormalen Vorganges sein.

Wenn wir den nächsten Fall zum Vergleich nehmen, so können wir es uns leicht vorstellen, dass diese Furche durch die Heilung eines Tumors entstanden ist. Der Beweisfall ist von Bramann beschrieben worden. 4 Tage *altes atrophisches Kind, aus dessem linken Nasenloch ein bohnengrosser* Tumor heraushing, der birnenförmig über die Oberlippe lag, mit seinem konischen Stiel in das Nasenloch eintrat, um hier in den Rand des Nasenflügels überzugehen. Der letztere war deutlich verkürzt und zeigte einen etwa dreieckigen Defekt, dessen Basis dem freien Rande des Nasenflügels entsprach, während er mit der Spitze bis zur halben Höhe der knorpeligen Nase hinaufreichte. An dieser Stelle inserierte der Tumor mit einem Stiele, der noch vor dem unteren Rande der knöchernen Nase vollends in den Nasenflügel überging. Aus dieser Beschreibung ist es ersichtlich, dass der Tumor weit hinauf bis zum inneren Nasenansatz und sicherlich bis in die Schädelhöhle reichte. Eine Röntgenaufnahme hätte die Frage vielleicht geklärt. Jedenfalls können wir aus diesem Fall den Schluss ziehen, dass die seitliche Nasenspalte mit dem Vorhandensein eines Tumors verbunden ist und wenn der Tumor nicht mehr sichtbar ist, bleibt eine Narbe, eine Furche oder eine geringgradige Spalte zurück.

Unser zweiter Fall, den wir in den Abbildungen 4 und 5 zeigen, liefert ein weiteres Beweismaterial zu unserer Behauptung. Wir haben ein 10 Tage altes Kind vor uns, an dessen linker Nasenseite unterhalb der Glabella eine mit Flüssigkeit gefüllte, fast kirschengrosse Zyste liegt. Wenn das Kind schreit, wächst die Zyste, wenn man sie drückt, kann ein Teil der Flüssigkeit weggedrängt werden. Das bedeutet soviel, dass die Zyste mit den Ventrikeln des Gehirns in Verbindung steht, was auch die Röntgenaufnahme bestätigt. Hier ist eine Längsspalte durch das ganze Nasenbein zu sehen. Wir können uns vorstellen, dass diese Zyste in einem frühen Embryonalstadium so gross gewesen sein konnte, wie im durch Bramann beschriebenen Fall, sich später aber zurückgezogen bzw. verkleinert hat, ohne einen Nasenflügeldefekt hinterlassen zu haben. Dieser Teil der Nase regenerierte sich in Form einer restitutio ad integrum. Wegen der Interposition konnte aber das Nasenbein



Abb. 5 Abb. 6

Abb. 5. Röntgenaufnahme vom selben Fall. Am linken Nasenbein ist ein Langsspalte zu sehen.

Abb. 6. Linksseitige totale Nasenspalte. Beiderseitige Anophthalmie bzw. Mikrophthalmie.

an dieser Stelle nicht mehr heilen bzw. weiter wachsen, so dass eine Spalte blieb. In der weiteren Entwicklung hätte sich diese Zyste vollständig abgeschnürt und es wäre wahrscheinlich nur eine isolierte Zyste zurückgeblieben. Es ist anzunehmen, dass der Gehirndruck viel zu gross war und die Regenerationsmöglichkeit verhinderte. Bei diesen verschiedenen Regenerations- oder Heilungsprozessen spielt ausser der Grösse der schädigenden Wirkung, ausser dem Zeitpunkt und der Zeitdauer der Schädigung auch die individuelle biologische Einstellung des Embryos eine Rolle.

Wir kennen genau die Fälle, in welchen eine Dermoidzyste des Nasenrückens sich bei der Operation als ein abgeschnürtes Gehirnteil entpuppt. Ich selbst habe Gelegenheit gehabt, zwei solche Fälle zu operieren und zu untersuchen. Diese Beobachtung mahnt uns, bei sogenannten Dermoidzysten des Gesichtes an abgeschnürte Reste eines Gehirndefektes zu denken, die grösstenteils intrauterin regeneriert oder geheilt sind.

Frangenheim (1909) zeigt uns zwei Fälle, bei denen im Ersten ein 2 Wochen altes Kind beschrieben wird, an dessen rechtem Nasenrücken eine von der Unterlage verschiebbare erbsengrosse Anschwellung (Dermoidzyste) sich befand und dessen rechter Nasenflügel ¼ cm tief gespalten war. Im zweiten Fall gibt Frangenheim eine 40jährige Frau an, deren Stirn eingedrückt war mit einer tiefen Furche in der Mittellinie. Bei intakten Knochen hatte der rechte Nasenflügel eine ½ cm tiefe Spalte. Eine Röntgenuntersuchung



Abb. 7

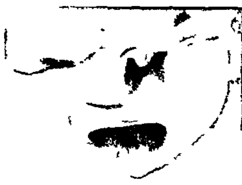


Abb. 8

Abb. 7. Derselbe Fall stärker vergrössert. Man sieht den linken Nasenflügel stark nach Oben gezogen. Unterhalb des Nasenflügels ist eine Nasenmuschel zu sehen.

Abb. 8. Auf der rechten Oberlippe ist eine Narbe zu sehen, die auf eine intrauterine Regeneration einer Lippenspalte hinweist.

hätte hier einige Probleme lösen können. Leider beschränken sich die meisten Beschreibungen auf den sichtbaren morphologischen Defekt.

Einen Übergang zu den schwersten Defekten zeigt uns Nash (1898) bei einem 6 Monate altem Kind: eine rechtsseitige unvollkommene Nasenspalte, das rechte Auge fehlt. Die Nase ist bis zum unteren Ende des Nasenbeines gespalten. An der Nasenspitze befindet sich ein kleiner Hautanhang, wahrscheinlich ein Überrest eines Tumorgebildes. Kindler (1898) beschreibt den folgenden schweren Defekt: 4½ Monate altes gestorbenes Kind mit schräger Spalte durch die linke Nasenhälfte vom Nasenloch bis zum inneren Augenwinkel. Das linke Nasenbein fehlt. Grosser Defekt im Bereich des Stirnbeines, hauptsächlich links, durch eine derbe fibröse Membran ausgefüllt, in deren Medianlinie ein ungefähr bohnengrosses eiförmiges Knochenstück eingelagert ist.

Zu diesem schweren Defekt reiht sich unser dritter Fall (Abb. 6, 7 und 8). Der Embryo musste mehrfache schwere Schädigungen erlitten haben, wie wir es auch später aus der Vorgeschichte tatsächlich erfahren haben. Die rechte Nasenhälfte ist anscheinend normal gebildet, dagegen fehlt die linke fast vollständig. Der knorpelige Nasenflügel liegt unterhalb der Stirnwölbung, die Nasenöffnung ist breit offen, aus dieser Öffnung ragt die eine Nasenmuschel hervor. Das Kind hat beiderseits Anophthalmie bzw. Mikrophthalmie, die Bulbi sind nicht zu sehen. Die Stirnnaht ist breit offen. Bemerkenswert sind zwei Erscheinungen. Weder die breit offene linke Nasenhälfte noch die rechte sind durchgängig, sondern sind in ungefähr 1–1½ cm Tiefe verschlossen und kommunizieren nicht mit dem hinteren Rachenraum. Die andere Merkwürdigkeit ist eine Narbe auf der rechten Oberlippe des Kindes, wie es in Abb. 8 besonders gut zu sehen ist. Diese Narbe stellt zweifellos eine intrauterin regenerierte Lippenspalte dar. Die Anamnese der Mutter gibt mehr oder weniger Aufschluss auf die Entstehung dieser Missbildung. Die

Mutter hat einen schweren Herzfehler. Im Anfangsstadium der Schwangerschaft (den genauen Zeitpunkt konnte sie nicht angeben) hatte sie starke Blutungen, wollte aber die Schwangerschaft nicht unterbrechen lassen. Nach einigen Tagen bekam sie eine schwere Dekompensation des Herzens und wurde ins Krankenhaus gebracht, wo ihr Herzfehler durch grosse Dosen Medikamente wieder kompensiert wurde. Die Blutung ist zum Stillstand gekommen. 5–6 Wochen nach dieser Dekompensation erlitt sie eine zweite Attacke, abermals mit Blutung. Die Herztätigkeit wurde wieder mit Medikamenten und Schonung geregelt. Bis zur Niederkunft hat sie keine Beschwerden mehr gehabt und das Kind ist zur normalen Zeit auf die Welt gekommen.

Der Embryo hat also zweimal schwere Schädigungen erlitten. Die Blutung wurde sicherlich durch die gestörte Herztätigkeit der Mutter verursacht. Zufolge der Schwangerschaft musste das Herz eine grössere, anstrengendere Arbeit leisten, die rasch zu einer Dekompensation führte, deren Ergebnis die Blutung war. Der beginnende Kreislauf des Keimlings wurde gestört und schon frühzeitig entstand die grosse Missbildung. Trotz der grossen Schädigung, die der Embryo erleiden musste, war seine individuell biologische Einstellung der Regenerationsfähigkeit so gross, dass er am Leben geblieben und lebensfähig zur Welt gekommen ist. Die Regenerationsfähigkeit wird auch durch die kleine Erscheinung der Narbe an der Lippe, also durch die intrauterin regenerierte Lippenspalte bewiesen. Die Entwicklung des Gehirns musste durch eine besonders schwere Schädigung gestört worden sein. Es scheint, als ob der intrakranielle Druck die Entwicklung der Seh- und Geruchsnerven gehemmt hätte. Die innere Nase war im Begriff, sich normal zu entwickeln, aber die Epithelmassen, die normalerweise bei der Entwicklung der inneren Nase vorhanden sind, haben sich so organisiert, dass sich das innere Nasenorgan nur teilweise entwickeln konnte. Die Membrana bucconasalis konnte sich nicht zurückbilden und so blieb die Nasenhöhle verschlossen. Wir stehen hier vor einem Missbildungskomplex, dessen Ausgangspunkt die Schädigung des Gehirns und des Schädels sein musste.

Bevor wir die Entstehungsmöglichkeiten dieser Nasenmissbildung kurz erörtern, sollen noch zwei Fälle gezeigt werden, die scheinbar nicht in das Problem der seitlichen Nasenspalte gehören, pathogenetisch betrachtet aber doch hier erwähnt werden können. Im Falle von Kindler haben wir gesehen, dass im Bereich des Stirnbeins eine derbe fibröse Membran vorhanden war. So eine ähnliche Erscheinung müssen wir bei unserem letzten Fall annehmen. Am lebenden Kind haben wir keine Möglichkeit, den Zusammenhang dieser fibrösen Masse mit den Nachbarorganen genau zu untersuchen, wir können nur die vorhandene Tatsache diagnostizieren, dass die Nasenhöhle verschlossen ist, wie auch das Röntgenbild zeigt. Wenn die Nasenspalte nicht die äussere Gestaltung der Nase betrifft, sondern die Entwicklung des Nasenorgans geschädigt wird, so kann eine innere Nasenhöhlenverwachsung entstehen, die zu einer sogenannten Arrhinie führt.

Wir haben bisher die Beobachtung gemacht, dass die Ursache der meisten Nasenspalten eine Geschwulst war, die durch die gestörte Gehirnentwicklung



Abb. 9.



Abb. 10.

Abb. 9. Arrhinie mit beiderseitigen Ohrdefekten.

Abb. 10. Arrhinie. Ein kleines Loch, welches nur ½ cm zu sondieren war, an Stelle des Nasenloches. Oberhalb dieses Loches ist eine narbige Einziehung, die auf eine vorhanden gewesene Nasenspitze hinweist.

entstanden ist. Wenn sich diese „Geschwulst" im Naseninnern entwickelt und sich als „Geschwulst" regeneriert — die Geschwulst als solche heilte — dann kann sich das Nasenorgan und auch die äussere Nase nicht entwickeln.

In unserem vierten Fall (Abb. 9) sehen wir eine Arrhinie, wo aber die Nasenbeine sich irgendwie doch entwickelt haben. Nasenlöcher sind nicht vorhanden, das ganze Mittelgesicht ist in der Entwicklung geschädigt worden, die äusseren Ohren sind nur durch kleine Hautanhänge angedeutet. Das Kind lebte 3 Wochen. Bei der Sektion zeigte es sich, dass das ganze Mittelgesicht eine einheitliche Knochen-Knorpelmasse war, weder die innere Nase noch innere Ohrgebilde und Nasennebenhöhlen waren vorhanden.

Ähnlich war unser fünfter Fall, den wir in den Abb. 10 und 11 zeigen. An der Stelle des rechten Nasenloches war nur eine kleine Öffnung, in welcher man nur ½ cm tief sondieren konnte. An Stelle der Nasenspitze sah man eine Narbe, die darauf hinweist, dass eine Nasenentwicklung vor sich gehen musste, doch hat sich die äussere Nase zurückentwickelt. Das Kind starb nach 3 Wochen und die Sektion zeigte ein ähnliches Bild wie bei Fall 4 (Abb. 12.) Im Querschnitt durch den Schädel sehen wir die zwei Bulbi, den Knorpel der Nasenscheidewand, aber keine Nasenhöhle. Die ganze Nasenhöhle bildete eine ziemlich einheitliche Masse, in welcher man Reste der Nasenmuscheln unterscheiden konnte. Das Siebbein war unvollständig



Abb. 11.

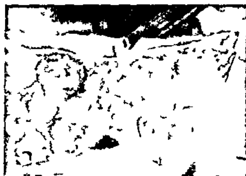


Abb. 12.

Abb. 11. Derselbe Fall von der Seite gesehen.

Abb. 12. Horizontalschnitt durch den Schädel. Zwischen den Bulbis ist die knorpelige Nasenscheidewand zu sehen, aber Nasenhöhle ist nicht vorhanden. Harter Gaumen ist stark gewölbt. Sichtbare Nasenscheidewand reicht nicht bis zum Gaumen.

entwickelt. Ausser einer ausgesprochenen Unterentwicklung konnte man im Gehirn makroskopische keine besondere Schädigung bemerken.

Wir haben eine Reihe der seltensten Gesichts- bzw. Nasenmissbildungen vorgeführt, aus denen wir zur Folgerung gelangt sind, dass diese Defekte sekundär entstanden sein mussten. Das Primäre war die Gehirnschädigung. Landow (1881) und auch die meisten Beobachter erklären die Ursache dieser Missbildungen mit mechanischen Defekten, vor allem werden die Amnionstränge beschuldigt. Wir haben jedoch keinen Anlass an Amnionschädigungen zu denken, denn nirgends konnte man Reste solcher Amnionfäden beobachten. In sämtlichen Fällen wurden irgendwelche Geschwulste festgestellt, die allein als mechanische Ursachen angenommen werden können. Tumoren sind nicht die Folgen von Amnionschädigungen, doch können Tumoren Nasenmissbildungen zur Folge haben. Interessanterweise nimmt Landow an, dass der Defekt im Stirnbein, also die letzte äusserlich noch wahrnehmbare Andeutung einer Meningocele, das Effekt einer von innen nach aussen wirkenden Gewalt sei, glaubt aber, es sei gleichgültig, ob der Hirnbruch respektive der Defekt im Stirnbein die Folge einer innerhalb der Schädelkapsel primär bestehenden Flüssigkeitsansammlung ist oder ob derselbe durch Zug eines an der betreffenden Stelle verwachsenen Stranges zustande kam. Hier meint Landow die Amnionstränge. Es ist aber überhaupt nicht

gleichgültig ob wir eine äussere oder eine innere Störung annehmen Die äussere Störung kann als mechanische Ursache nur die äussere Gestalt schädigen, während die innerhalb der Schädelkapsel entstandene Störung auch andere Schädigungen hervorrufen kann, die wir suchen und diagnostizieren müssen wenn wir nicht nur den lokalen Defekt heilen wollen Wir sehen einen morphologischen Defekt, welcher mit solchen äusserlich nicht sichtbaren Defekten vergesellschaftet ist, die wir erforschen müssen

Es ist nicht die Aufgabe des Klinikers, die einzelnen embryologischen Geschehnisse zu klären Unsere Pflicht besteht darin, unsere Beobachtungen klar darzustellen mit dem Hinweis, wie wir einige Entwicklungsstörungen auf Grund klinischer Erfahrungen uns vorstellen Dies ist die Aufgabe der klinischen Embryopathologie und dies wollte ich mit den hier beschriebenen Auseinandersetzungen beweisen

SUMMARY

The lateral fissure of the nose is a very rare malformation On the basis of my own cases, and after a critical review of the cases described in the literature, we come to the conclusion that these defects of the nose are of secondary origin, while the primary cause is an injury of the brain or skull In each of the cases some tumour could be found, one part of which recovered intra uterinely The clinician often observes phenomena which show that the embryo possesses a capacity of intra uterine regeneration which we could also confirm in the enumerated cases In the present discussions we wish to prove that clinical experience and observations may give us information on several embryologic and pathobiologic phenomena Therefore it is the task of the clinician to consider the malformations not from the therapeutic point of view only but to examine the defects of the different organs in their connection and in their relation to the neighbouring organs and to the organic system Even the smallest deviation from the normal condition can give us information on defects which are not visible but which may eventually be confirmed by diagnosis

RÉSUMÉ

La fissure latérale du nez est une malformation très rare Sur base de mes propres cas et après la revue critique des cas décrits dans la littérature nous arrivons à la conclusion que ces défectuosités nasales ont une origine secondaire tandis que la cause primaire est une lésion du cerveau ou du crâne On a trouvé dans chacun des cas quelque tumeur une partie desquelles « guérissait » intra utérinement Le clinicien voit souvent des phénomènes qui montrent que l'embryon possède la capacité d'une régénération intra utérine Aussi dans les cas énumérés nous pouvions constater cette régénération intra utérine Les discussions présentes ont le but de prouver que expérience et les observations cliniques peuvent fournir des renseignements sur quelques phénomènes embryologiques et pathobiologiques Cela impose au clinicien la tâche d'observer les malformations non seulement du point de vue thérapeutique, mais d'examiner les défectuosités des organes différents dans leur

connexion et dans leur rapport avec les organes voisins et avec l'entier système organique Même les déviations les plus petites de l'état normal peuvent nous donner des instructions sur des défectuosités quoique invisibles mais éventuellement à diagnostiquer

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EMPFINDUNG BINAURALER ZEITDIFFERENZEN BEIM KNOCHENLEITUNGSHÖREN VON IMPULSEN

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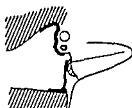
Der Knochenschall von kurzen Druckimpulsen (0,1 msec Dauer, 30 dB) hat einen psycho-akustisch nachweisbaren Zeitbedarf für die Überwindung der Wegstrecke zwischen beiden Innenohren. Durch Messung der oberen zeitlichen Fusionsgrenze an Normalpersonen sowie am einohrig tauben Patienten konnte er mit mindestens 0,3 msec bestimmt werden. — Die Lateralisation von Druckimpulsen befolgt nicht die Regeln des Weberschen Versuches bei Puls-Folgefrequenzen kleiner als 50/sec, sondern bewirkt stereophone Empfindungen in Abhängigkeit vom Ort des Knochenschallgebers, aber unabhängig von Schalleitungsstörungen oder Gehörgangsverschluß. — Die Ergebnisse werden mit Laufzeitdifferenzen zu beiden Innenohren interpretiert, die beim Knochenleitungshören von Einschwingungsvorgängen (Transients) auftreten können.

Prüft man die Knochenleitungs-Schwellen von Patienten, deren Mittelohr tympanoplastisch zum Typ IV nach Wullstein umgebaut ist, so kann man fast beliebig viele Normalschwellen darunter finden. Fig. 1*a* demonstriert, daß das ovale Fenster — bedeckt nur mit einem Thiersch-Transplantat (Wullstein 1957) — frei in den Gehörgang sieht, während das runde Fenster in die sog. »kleine Pauke« mündet.

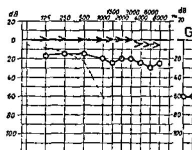
Von einer Schalleitungskette mit Masse-Eigenschaften ist praktisch nichts mehr vorhanden. Fig. 1*b* zeigt das Audiogramm eines solchen Patienten mit etwa dem zu erwartenden (Wullstein 1955) Hörverlust in der Luftleitung und mit normaler Knochenleitungsschwelle.

Für eine befriedigende Erklärung des Knochenleitungshörens kann man demnach die älteren Hypothesen außer Betracht lassen, die eine Schalleitungskette mit Masse-Eigenschaften zum Knochenleitungs-Hören voraussetzen. Sei es, daß sie Schallfluß vom Labyrinth in den Gehörgang bewirken sollte (Mach) oder vom Schädel in das Labyrinth hinein (Bezold), oder daß sie zur Veranlassung von Trägheitsbewegungen der Steigbügelfußplatte dienen sollte (Herzog und Krainz). Auch vom klassischen Werk E. Baranys sind demnach Abstriche vorzunehmen.

Ein weiteres Beispiel (Fig. 2) soll zeigen, daß auch die gegenwärtigen Ansichten über die Physik des Knochenleitungs-Hörens der experimentellen Erweiterung bedürfen. Das gezeigte Audiogramm gehört zu einem 7jährigen



a) Tympanoplastik Typ IV (Schema)



b) Tympanoplastik Typ IV (Audiogramm)

Fig. 1. (a) Schema einer Tympanoplastik Typ IV nach Wullstein. Die Gehörknöchelchen sind entfernt. Das ovale Fenster ist durch ein separates Thiersch-Transplantat gedeckt, die kleine Pauke durch frei transplantierte Haut abgeschlossen. (b) Audiogramm eines Patienten mit Tympanoplastik Typ IV nach Wullstein (Ro. H. 14 J. 114 489). Schalleitungsstörung von 15–25 dB bei normaler Knochenleitungsschwelle. Vertäubung des Gegenohres mit weißem Rauschen von 60 dB.

Knaben mit einer Mittelohrmißbildung. Unter dem Operationsmikroskop konnte nachgewiesen werden, daß die Schnecke nur ein Fenster hatte (Fenestra rotunda). Das ovale Fenster fehlte.

„*Tympanoplastik Typ V, 1. Teil* (Hau. Wolfgang, 7 Jahre — 119912). Hammer normal geformt. Kein Amboß. Chorda vorhanden, sehr steile runde Nische vorhanden. Stark überhängendes Promontorium. Keine ovale Nische, statt dessen verläuft hier der Facialisnerv im knöchernen Kanal. Abbau der Brücke, Freilegung des Labyrinthblockes ohne wesentliche Verdünnung. Hammer entfernt. 5. 2. 1962."

Nicht besonders erwähnt wurde in diesem Operationsbericht, daß die Mittelohrschleimhaut sonst reizlos und zart war und eine genaue Inspektion und Abtastung der knöchernen Mittelohrwände ermöglichte.

Im zugehörigen Audiogramm (Fig. 2) ist weniger die starke Schalleitungskomponente der Schwerhörigkeit interessant als vielmehr der Nachweis, daß von dieser Schnecke ein Knochenleitungston normaler Schwellenschallstärke gehört wurde bzw. von nur 20–30 Dezibel über der normalen Schwellenschallstärke für die Frequenzen über 500 Hz. Fälle dieser Art sind in einer ohrchirurgischen Klinik keine Seltenheit. Auch die gültigen Theorien des Knochenleitungshörens (v. Békésy 1932, 1941; Ranke 1952, 1953), die zur Erregung des Cortischen Organes eine Hydrodynamik der Ohr

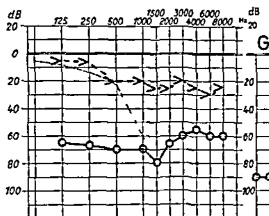


Fig. 2. Audiogramm bei Mittelohrfehlbildung und Gehörgangsatresie. Das ovale Fenster ist nicht vorhanden. Einzelheiten im Text. Mäßiger Hörverlust in der Knochenleitungsschwelle, starker Hörverlust in der Luftleitungsschwelle. Vertäubung des Gegenohres mit weißem Rauschen bis zu 90 dB (Hau., Wolfgang, 7 J., 119 91?)

schnecke mit je einem elastischen Abschluß der beiden Skalen in irgendeiner Form verlangen, lassen demgegenüber noch Fragen offen, vor allem wegen der Verhältnisse nach Fenestration. Auf ergänzende Hypothesen wie jene mit Druckausgleich über den Aquaeductus cochleae oder über den inneren Gehörgang (Ranke, vgl. hierzu auch Schneider) kann hier nicht eingegangen werden. Zwei verschiedene Mechanismen sollen das Innenohr über Knochenleitung anregen:

1) Die Schwingungsform der Basilarmembran ist bei Knochenleitung identisch mit der bei Luftleitung (v. Békésy 1941). Die Bewegung der Steigbügelfußplatte kann daher ersetzt werden durch allseitige Kompression der Vestibulumwände (v. Békésy). Der Rest an Knochenleitungs-Gehör, der bei völliger Stapesankylose übrigbleibt, ist physikalisch nur oder wenigstens ganz überwiegend auf diese *Volumenkompression* am Ort der Verdichtung der den Knochen durchsetzenden Schallwellen zu erklären (Ranke 1953). Für diese Anregungsart haben Allen und Fernandez (1960) nachgerechnet, daß beim Aufsetzen des Knochenschallgebers auf eine Kopfseite die Differenz der Ankunftszeit der Kompressionswellen an beiden Innenohren vernachlässigt werden kann. Selbst bei Zugrundelegen der von v. Békésy (1948) mitgeteilten, recht geringen Fortleitungsgeschwindigkeit des Knochenschalles von 570 m/sec würde sich eine Phasendifferenz von nur 40° ergeben.

2) Der zweite Mechanismus, dem man heute Bedeutung beimißt, ist die Auslösung der Perilymphschwingungen durch *Massenkräfte* (Zusammenfassendes bei Ranke 1953). Da der Schädel, angeregt durch Knochenschall, erzwungene horizontale Translationsbewegungen ausführt — unterhalb von 1500 Hz schwingt er als ganzes (v. Békésy 1932, 1948) —, kommt es zu Relativbewegungen der massenträgen Perilymphe. Da die beiden Schneckenskalen verschiedene Masse besitzen, entstehen frequenztreue Druckdifferenzen beiderseits der Basilarmembran, durch sie wird das Cortische Organ

erregt (Ranke). Einzelheiten über die Rolle der Kiefergelenke bei v. Békésy (1932). Beide Ohren wurden demnach gleichzeitig und mit einem festen Phasenwinkel vom Schall getroffen.

Nun hat sich das umfangreiche Schrifttum (wesentliche Übersichten bei E. Barany und J. H. Huizing, vgl. auch Kley) fast ausschließlich mit der Verwendung von reinen Tönen (Sinusoiden) beschäftigt, die als Dauerton gegeben wurden. Nur v. *Békésy* macht eine Mitteilung über die Knochenschalleitung von Impulsen, die Einschwingungsvorgänge bzw. »Transients» darstellen, wenn man von klinischen Arbeiten über die Sprachaudiometrie mittels Knochenleitung (Fato, Hahlbrock) absieht. Es wurden also für die Theorie der Knochenleitung vor allem Messungen der Knochenleitung im eingeschwungenen Zustand des Schädels und des Mittelohr-Innenohrsystems berücksichtigt. Fügt sich die Knochenleitung während des Einschwingungszustandes überhaupt in diese theoretischen Betrachtungen?

Den Knochenschall von Impulsen benutzend, will diese Arbeit über Teilfragen des Knochenleitungs-Hörens Aufschluß geben und zeigen, daß Druckwellen im Schädel fortgeleitet werden können, deren meßbare Leitungsgeschwindigkeit[1] dazu führt, daß binaurale Differenzen des Erregungszeitpunktes auftreten können. Sie fallen in den Zeitbereich von Fusionsvorgängen und in den Bereich des Richtungshörens. Vielleicht sind sie deshalb beim Knochenleitungs-Hören von Geräuschen und Sprache, die auch vorwiegend aus »Transients» bestehen, nicht ganz nebensächlich.

METHODIK

Als akustische Reize wurden periodische Impulsfolgen benutzt. Produziert von zwei Rechteck-Impulsgeneratoren (Tektronix 161) und zeitlich gesteuert durch einen Sägezahngenerator (Tektronix 162) wurden Rechteckimpulse der Impulsdauer 0,1 msec nach geeigneter Verstärkung und Filterung sowohl auf ein Knochenschall-Telefon mit einer runden Abstrahlfläche von 11 mm Durchmesser (Jaquet, Basel) wie auf einen von zwei gleichzeitig den Ohren *anliegenden Beyer DT48 Kopfhörern gegeben. Durch zwei in Dezibel* Stufen geeichte Dämpfungsglieder (Radiometer LP7) konnte die Schallstärke für beide Impulse unabhängig voneinader reguliert werden. Sie betrug in allen Testreihen sowohl für Knochenleitungs-Schall wie für Luftleitungs-Schall etwa 30 Dezibel über der Hörschwelle, damit ein Überhören des Luftleitungs-Impulses vermieden wurde.

Vielleicht von Bedeutung ist, daß der mit diesen Impulsen der Impulsdauer 0,1 msec angestoßene Schwingungsvorgang der Kopfhörer nach 1 msec praktisch beendet ist (reduziert auf weniger als ein Zehntel Amplitude). Der entsprechende Schwingungsvorgang des *Knochenleitungshörers* ist nach 2 msec beendet.

[1] Die zusammen mit H. G. Schmitt durchgeführten physikalischen Messungen der Leitungsgeschwindigkeit von Knochenschall im Schädel des Menschen sollen an anderer Stelle veröffentlicht und diskutiert werden.

Mit diesen Impulsfolgen wurde an 6 trainierten normalhörenden Personen in jeweils 5 Durchgängen u. a. folgendes Programm durchgeprüft:

1) Das Knochenschall-Telefon liegt dem rechten Planum mastoideum an. Die Kopfhörer bedecken beide Ohrmuscheln mit ihren flachen Gummimuffen. Mit einer Folgefrequenz von 2/sec wird jetzt jeweils ein Knochenleitungs-Impuls gegeben, und in variablem Zeitabstand von diesem Knochenleitungs-Impuls wird ein verzögerter Impuls auf den gleichseitigen rechten Kopfhörer gegeben. Das gegenseitige Ohr bleibt mit einem Hörer bedeckt, damit beiderseits gleiche Abdeckungsbedingungen bestehen; es erhält jedoch keinen Schallreiz. Das Zeitmuster des Reizes ist in Fig. 3 (untere Reihe) veranschaulicht. Es wird in mehreren Durchgängen das Zeitintervall vom Hörer erfragt, bei dem der Luftleitungs-Impuls gerade nicht mehr mit dem zuvor kommenden Knochenleitungs-Impuls fusioniert wird, sondern als eben wahrnehmbares Nachklappen getrennt empfunden wird.

Es wird, mit anderen Worten, die obere monaurale Fusionsgrenze für Luftleitungs-Impulse nach Knochenleitungs-Impulsen bestimmt. Die Verzögerungszeiten wurden mit dem Drehknopf des Triggers vom Impulsgenerator gewählt und auf dem Doppelstrahl-Oszilloskop (Tektronix 502) — vom Hörer ungesehen — kontrolliert. Zur oberen zeitlichen Fusionsgrenze von Impulsfolgen vgl. auch Wigand (1962).

2) Das Knochenschall-Telefon liegt wieder dem rechten Mastoid an. Die Kopfhörer bedecken beide Ohrmuscheln, allerdings sind sie jetzt seitenvertauscht, so daß der mit dem Impulsgenerator verbundene Kopfhörer diesmal auf dem linken Ohr sitzt. In gleicher Weise wie unter 1) wird die obere Fusionsgrenze für einen Knochenleitungs-Impuls (unverzögert) und einen Luftleitungs-Impuls (verzögert) bestimmt. Das Reizmuster ist in Fig. 3 (obere Reihe) wiedergegeben. Da der Luftleitungs-Impuls jetzt das gegenüberliegende linke Ohr allein trifft, wird sinngemäß die obere Zeitgrenze einer binauralen Fusion zwischen rechtem Ohr (angeregt durch den Knochenleitungs-Impuls) und linkem Ohr (angeregt sowohl durch Knochenschall wie durch den verzögerten Luftleitungs-Impuls) bestimmt.

3) Bei einer Patientin, deren linker Hörnerv in einem neurochirurgischen Eingriff durchtrennt war und deren rechtes Ohr normalhörig war, wurde folgendermaßen geprüft: Das hörende Ohr bekam die Luftleitungs-Impulse zugeleitet. Der Knochenschall wurde dagegen einmal dem rechten, in einem anderen Durchgang dem linken Mastoid zugeleitet. Für beide Anordnungen wurde die obere zeitliche Fusionsgrenze zwischen Knochenleitungs-Impuls (unverzögert) und Luftleitungs-Impuls (verzögert) gemessen. In beiden Fällen muß es sich natürlich um die Bestimmung der monauralen Fusionsgrenze handeln, denn das linke Ohr war absolut taub. Der einzige Unterschied beider Anordnungen lag in der Wegstrecke für den Knochenleitungsschall.

4) Von normalhörenden Versuchspersonen wurde die Lateralisation von periodischen Pulsfolgen der oben bezeichneten Pulsdauer und Intensität in Abhängigkeit von der Puls-Folgefrequenz erfragt, wenn der äußere

Gehörgang einer Seite leicht mit der Hand verschlossen war (Occlusion effect Wheatstone Tortual Weber zit nach Huizing) Der Knochenschall geber wurde abwechselnd auf das linke und rechte Planum mastoideum gesetzt

5) Von Patienten mit Schalleitungsstörungen die eindeutig die Stimm gabeln c² und c³ — auf welcher Stelle des Schädels sie auch aufgesetzt sein möchten — in das kranke Ohr lateralisierten (Weber Test positiv) wurde die Lateralisation von Knochenleitungs Impulsen in Abhängigkeit von der Folgefrequenz der Impulse erfragt Dabei saß das Knochenleitungs Telefon einmal dem Mastoid des kranken Ohres und einmal dem des gesunden Ohres auf

ERGEBNISSE

1) In der ersten Versuchsreihe wurde das zeitliche Auflösungsvermögen eines Ohres zwischen einem über Knochenleitung zugeführten Impuls (Click Knack) und einem verzögerten über Luftleitung demselben Ohr zugeführten Impuls untersucht Werden beide zur gleichen Zeit ausgelöst wird nur ein Click gehört Nach einer gehörigen Mindestzeit wird der ver zögerte Click als kurzes Nachklappen eben hörbar Diese Mindestverzögerung wird als obere Zeitgrenze der monauralen Fusion betrachtet Sie betrug in der Anordnung Knochenleitungs Impuls (unverzögert) — Luftleitungs Impuls (verzögert) unter den oben angegebenen Bedingungen 4,7 msec Das ist ein Mittelwert von 6 trainierten Normalpersonen Er hatte einen mittleren Fehler von 0,2 msec

In dieser Versuchsanordnung (vgl Fig 3 untere Reihe) geht der Schall fluß vom Knochenleitungs Telefon auf das rechte Mastoid von hier über Knochenleitung auf das rechte Innenohr Zugleich fließt Schallenergie vom rechten Mastoid über Knochenleitung ins linke Felsenbein und trifft hier auf das linke Innenohr Der Weg zum linken Innenohr ist weiter als zum rechten Der auf das linke Innenohr gelangende Anteil der Schallenergie ist im Experiment eine Unbekannte

In Vorversuchen wurde gefunden daß die obere Zeitgrenze der Fusion von zwei nacheinander über Luftleitung auf das rechte Ohr gegebenen Impulsen nur etwa 2 msec betrug

2) In der zweiten Testreihe wurde das zeitliche Auflösungsvermögen des Gehörs zwischen einem dem rechten Mastoid zugeführten Knochenleitungs Impuls (unverzögert) und einem dem linken Ohr zugeführten Luftleitungs Impuls (verzögert) bestimmt Die gefundene Mindest Verzögerung wird als obere Zeitgrenze eines binauralen Fusionsvorganges betrachtet Sie betrug unter den oben bezeichneten Bedingungen 5,6 msec Das ist ein Mittelwert von 6 trainierten normalhörenden Versuchspersonen Er hatte einen mittleren Fehler von 0,1 msec

In dieser Anordnung war der Energiefluß des Knochenschalles identisch mit dem unter 1) betrachteten Lediglich der Luftleitungs Impuls wurde jetzt auf das gegenüberliegende linke Ohr gegeben Das rechte Ohr hörte

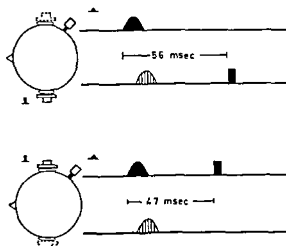


FIG 3 Zeitmuster der Reizung mit Impulsen zur Messung der oberen Zeitgrenze der monauralen und binauralen Fusion Der Impuls vom Knochenleitungs Telefon auf dem rechten Mastoid trifft bei ▲ auf die rechte Cochlea und bei △ auf die linke Cochlea Nach geeigneter Verzögerung wird ein Luftleitungs Impuls aus dem Kopfhörer bei ▮ im gleichseitigen rechten Ohr (untere Skizze) bzw im gegenseitigen linken Ohr (obere Skizze) getrennt hörbar Einzelheiten im Text

über Luftleitung nichts seine Ohrmuschel war von der Muffe des nicht angeschalteten Kopfhörers bedeckt

Natürlich wird auch im linken Ohr von dem das rechte Mastoid treffenden Knochenschall eine Erregung ausgelöst Sie wird über den Hörnerven in die zentrale Hörbahn geleitet kommt allerdings nicht zur getrennten Wahrnehmung Ein auf dieses Ohr gehender verzögerter Impuls kann erst dann empfunden werden wenn das linke Ohr wieder aufnahmefähig ist (Leitung frei)

Es mag sein daß zwei Dinge entscheidend sind a) Die Zuleitung (Cochlea und Hörnerv) muß aus der absoluten und relativen Refraktärphase heraussein und b) der zentralnervöse Empfindungsmechanismus muß bereit sein das verzögerte Signal getrennt zum Bewußtsein zu bringen Da vom Knochenleitungs Impuls beide Ohren erregt werden mögen binaurale Hemmungserscheinungen ins Spiel kommen Über ihre Bedeutung für die gefundenen Zeiten kann hier nichts ausgesagt werden

In Vorversuchen war die obere Fusionsgrenze von zwei binaural gegebenen Luftleitungs Impulsen der oben bezeichneten Dauer und Intensität mit etwa 3 msec bestimmt worden Diese Zeit ist deutlich kleiner als die Mindest Verzögerung zwischen dem Knochenleitungs Impuls rechts und dem Luftleitungs Impuls links (s o)

Es wird daher angenommen daß der Vergleich der unter 1) und 2) angegebenen Grenzzeiten der monauralen bzw binauralen Fusion etwas aussagt über den Zeitpunkt der Knochenschall Erregung in beiden Ohren Da eine signifikante Differenz dieser beiden Zeiten besteht erscheint die

Annahme berechtigt, daß beide Ohren von *einem* auf das rechte Mastoid gegebenen Impuls *nicht gleichzeitig* erregt werden. Vielmehr besteht eine Zeitdifferenz, die im psycho-physischen Versuch annähernd bestimmt werden kann und demnach Einfluß auf die Art der Hörempfindungen haben könnte. Da der Weg vom rechten Mastoid zum linken Innenohr um ca. 10 bis 20 cm weiter ist als vom rechten Mastoid zum rechten Innenohr, muß man die betrachtete Zeitdifferenz als eine *Laufzeitdifferenz* interpretieren. Es sei einschränkend bemerkt, daß vielleicht nicht die ganze Differenz von ca. 0,9 msec zu Lasten der Wegdifferenz geht, evtl. kommen noch unbekannte Vorgänge im binauralen Fusionsmechanismus der drei (!) Hörerregungen hierbei zum Vorschein.

3) Es bestand Gelegenheit, eine sicher einseitig taube Patientin nach den hier interessierenden Gesichtspunkten zu untersuchen. Sie erschien für derartig diffizile Empfindungs-Prüfungen hinreichend geeignet. Sie lieferte bei wiederholten Prüfungen ohne Kenntnis des Zusammenhanges folgende Werte:

Bei Zuführung des Luftleitungs-Impulses (verzögert) auf das hörende rechte Ohr und Zuführung des Knochenleitungs-Impulses (unverzögert) auf das rechte Mastoid betrug die Mindest-Verzögerung für das Getrennthören 3,6 msec.

Bei Zuführung des Luftleitungs-Impulses (verzögert) auf das hörende rechte Ohr und Zuführung des Knochenleitungs-Impulses (unverzögert) auf das linke Mastoid betrug die Mindest-Verzögerung 3,9 msec. Diese Zeiten sind Mittelwerte aus 20 Durchgängen mit einem mittleren Fehler von 0,16 msec. Sie wurden an verschiedenen Tagen ermittelt.

Da in diesen Prüfungen jedesmal die obere Zeitgrenze der monauralen Fusion bestimmt wurde und mit Sicherheit keinerlei binaurale Fusionsvorgänge beteiligt waren, kann die gefundene Differenz von 0,3 msec ganz allein auf den *Ortsunterschied der Knochenschall-Ankopplung bezogen* werden.

An dieser Stelle könnte, wie schon weiter oben, eingewendet werden, daß nicht nur der Aufsatzpunkt des Knochenschall-Telefons verändert wurde. Dadurch bedingt dürfte eine gewisse Schallabschwächung für den Knochenschall-Impuls entstehen, der vom einen Mastoid zum gegenüberliegenden Innenohr laufen muß, es würde also eine weitere Unbekannte in das Experiment eingeführt. — Eine solche Intensitätsminderung könnte jedoch höchstens den Zeitpunkt der Hörnervenerregung hinausschieben (Latenzzeitzunahme mit abnehmender Reizintensität, vgl. Keidel *et al.*, 1960). *Ihre rechnungsmäßige Berücksichtigung würde die gefundene Laufzeitdifferenz* also eher noch vergrößern. Die Luftleitungsimpulse waren in allen Prüfungen einer Versuchsperson identisch.

4) Wie eingangs besprochen, bietet die Literatur zur Physiologie des Knochenleitungs-Hörens keine Hinweise auf binaurale Zeitdifferenzen, die in den wahrnehmbaren Bereich fallen. Wahrscheinlich liegt dies nur daran, daß Messungen vor allem des eingeschwungenen Zustandes durchgeführt

Impuls Folge frequenz/sec	Urteile über die Lateralisation
2	Rechts
5	Rechts
10	Rechts
20	Rechts
50	Rechts bis Mitte
100	Links
200	Links
500	Links
1000	Links

Fig 4 Einfluß der Puls *Folgefrequenz* auf die Lateralisation von *Knochenschall Impulsen* Durchschnitts Urteile normalhörender Versuchspersonen (Rechteck Impulse von 0 1 msec Dauer und 40 dB Lautstärke auf das rechte Planum mastoideum gegeben Linker äußerer Gehörgang leicht zugehalten) Erläuterung im Text

wurden (Dauertonreizung) Da das Knochenleitungs Hören von Einschwingungsvorgängen (Transients) wie gezeigt auf wahrnehmbare binaurale Zeitdifferenzen hinweist interessierte es die klassischen Phänomene des Knochenleitungs Hörens auch mit Impulsen zu überprüfen Größenordnungsmäßig werden binaurale Zeitdifferenzen empfindlicher wahrgenommen als binaurale Intensitätsdifferenzen (Keidel *et al* 1960) Daher lag die Vermutung nahe daß die Lateralisations Tests (z B Weber) bei Verwendung von Impulsen anders als gewohnt ausfallen würden

An den 6 normalhörenden Versuchspersonen wurde deshalb die Lateralisation von Knochenschall Impulsen erfragt wenn nur *ein* Gehörgang leicht verschlossen war Traf der Knochenschall auf das Mastoid der Seite deren Gehörgang äußerlich verschlossen war, lateralisierten alle Hörer in das verschlossene Ohr

Wurden dagegen die Impulsfolgen auf das Mastoid gegeben das dem verschlossenen Ohr gegenüberlag so bestand eine Abhängigkeit von der Folgefrequenz der Impulse (Fig 4) Langsame Clickfolgen wurden eindeutig von sämtlichen Hörern in die Kopfseite oder in das Ohr lateralisiert auf dessen Mastoid die Impulse gegeben wurden das also dem Knochenleitungs Telefon näher lag Dabei spielte eine Verschiebung desselben um mehrere Zentimeter überhaupt keine Rolle Man kann leicht nachprüfen daß sogar in der Nähe der Medianebene des Kopfes diese Regel noch gilt

Mit zunehmender Folgefrequenz wurden die Urteile unsicherer und für höhere Pulsfrequenzen als 100 sec gelten dann wieder eindeutig die Regeln des Wheatstone Weberschen Versuches d h es wird in das abgeschlossene Ohr lateralisiert Für diese höheren Folgefrequenzen haben die Impulse allerdings wieder klaren Ton bzw Klangcharakter und es liegt nahe diesen Umschlag auf den Wechsel vom Einschwingungszustand (langsame Pulsfolgen) zum eingeschwungenen Zustand (schnelle Pulsfolgen) zu beziehen

5) An mehreren Patienten mit einseitiger Schalleitungsstörung (Otitis media chronica) wurde der Webersche Versuch mit Impulsen nachgeprüft. Während die Stimmgabeln c² und c³ von ihnen stets in das kranke Ohr lateralisiert wurden, unabhängig vom Ort ihres Aufsetzens, wurden Impulsfolgen niederer Folgefrequenz stets in das Ohr lateralisiert, das dem Knochenschallgeber näher lag. Für Folgefrequenzen um 100/sec bestand Unsicherheit, d. h. die Antworten lauteten „Mitte" oder „beide Ohren", während höhere Folgefrequenzen klar in das kranke Ohr lateralisiert wurden. Eine Abhängigkeit des Lateralisationseffektes von der Lautstärke bestand nicht.

Zur Klärung dieses Verhaltens im Weberschen Versuch mit Impulsen war auszuschließen, daß die Impulse erst gleichzeitig gefühlt wurden. Das Zusammenwirken von sensiblen Erregungen aus der Haut oder dem Periost mit dem Höreindruck (Interferenz verschiedener Sinnesmodalitäten, intersensory interaction) konnte theoretisch eine Rolle spielen, da der sensible Reiz ein zusätzliches Zeitsignal liefern kann. Dieser Einwand ist nicht stichhaltig aus Gründen der Leitungszeit in der afferenten sensiblen Bahn und der Überleitungszeit auf sensorische Synapsen. Sicherheitshalber wurde die Lateralisation von weißem Rauschen im Weberschen Versuch überprüft, dessen überwiegend hörbare Frequenzen oberhalb des fühlbaren Vibrationsbereiches (Keidel) lagen. Auch für dieses Rauschen gelten jedoch im wesentlichen die Verhältnisse des Knochenleitungshörens von Impulsen.

DISKUSSION

Die Theorie des Knochenleitungshörens bietet auch heute noch offene Fragen (Keidel 1959). Sie erscheint gesichert, soweit sie feststellt, daß das Hören eines Knochenleitungsschalles durch dieselben Basilarmembranschwingungen angeregt wird, wie sie durch Anregung über Luftschall bewirkt werden (v. Békésy 1941). Gesichert erscheint ferner, daß die Anregung von Perilymphschwingungen zu beiden Seiten der Basilarmembran sowohl durch Volumenkompression wie durch Massenträgheitskräfte in den beiden ungleich belasteten Schneckenskalen zustande kommen kann (v. Békésy 1932, Ranke 1953). Wird der Schädel mit einem Knochenleitungston beschallt, so schwingt er in Frequenzen unter 1800 Hz als ganzes hin und her, während sich bei höheren Frequenzen mehrere Druckknoten und -bäuche ausbilden (v. Békésy 1932).

Für beide Anregungsarten (Volumenkompression und Massenträgheit) wurde angenommen, daß beide Schnecken so gut wie gleichzeitig vom Schallvorgang erreicht werden, so daß Phasendifferenzen der beiden Basilarmembran-Schwingungen zu vernachlässigen seien (Barany, Allen und Fernandez). — Außerdem besteht Einhelligkeit im Schrifttum, daß beide Ohren über Knochenleitung mit fast derselben Intensität erregt werden. Einen wesentlichen „Kopfschatten" für Knochenschall gibt es nicht.

Diese Arbeit strebt keine Revision der gültigen Knochenleitungs-Theorien

an, noch will sie in den alten Streit eingreifen (vgl. bei F. Barany) und einen der beiden Knochenleitungs-Mechanismen (Volumenkompression — Anregung durch Massenträgheit) begünstigen. Sie zielt auf nicht mehr und nicht weniger als auf den Nachweis ab, daß der Knochenschall von Impulsen geringer Intensität (30 dB) sich mit einer bestimmten Geschwindigkeit im Schädel ausbreitet. Diese ist meßbar auf physikalischem und auf psychoakustischem Wege. Zunächst ist nur der Zeitbedarf für das Zurücklegen eines Weges zwischen zwei Meßpunkten feststellbar. Bei Kenntnis der Wegstrecke läßt sich daraus die Knochenleitungs-Geschwindigkeit errechnen.

Der Nachweis eines Zeitbedarfes von Knochenschall für die Überwindung einer Wegstrecke im Schädel wurde hier aufgrund subjektiver Horempfindungen geliefert. Bei geeigneter Wahl des Startpunktes von Knochenschall (z. B. Aufsetzen des Knochenschall-Telefons auf das Planum mastoideum) können nämlich beide Innenohren zu meßbar verschiedenen Zeitpunkten erreicht werden. Man muß als Knochenschall allerdings Schallereignisse mit scharfem Einsatz und mit raschem Abklingen, sog. Übergangsfunktionen (Transients), benutzen. Sie standen in Form von Rechteck-Impulsen kurzer Impulsdauer zur Verfügung.

Werden zwei identische Rechteckimpulse auf Kopfhörer und auf Knochenschallgeber geschaltet, so entstehen gewöhnlich nichtidentische Schallereignisse. Sie sind sich akustisch jedoch so ähnlich, daß sie vom Gehör ohne weiteres zur Fusion gebracht werden können, wenn sie nur zeitlich annähernd gleichzeitig eintreffen (kohärente Signale). Gibt man die beiden Schalle nicht gleichzeitig, sondern läßt die Verzögerung des einen stetig anwachsen, so werden beide bei einer recht scharf reproduzierbaren Mindest-Verzögerung getrennt wahrnehmbar. Dies gilt für die Beschallung eines Ohres mit beiden Impulsen (monaurale Fusion) wie für die Beschallung beider Ohren mit je einem der beiden Impulse (binaurale Fusion).

Durch Bestimmung der oberen zeitlichen Fusionsgrenze nach dem Schema der Fig. 3 wurde eine signifikante Zeitdifferenz von 0,9 msec zwischen den Ergebnissen der beiden Versuchsanordnungen gefunden. Im vorangehenden Abschnitt wurde argumentiert, daß diese Zeitdifferenz wenigstens teilweise auf den Zeitbedarf des Knochenschall-Impulses für den Weg von einem Felsenbein zum anderen bezogen werden muß. Der Weg des Schalles vom Mastoid zu den beiden Innenohren bzw. seine Energieverteilung auf beide ist nicht genauer bekannt. Ob der wesentliche Schallanteil über die harten Strukturen der Schädelbasis geleitet wird oder über das Planum occipitale eilt, oder ob Druckwellen durch das Schädelinnere laufen, ist offene Frage. Schätzt man die Entfernung ganz willkürlich und unzureichend für die normale Versuchsperson auf 15 bis 25 cm und legt eine Mindestzeit von 0,3 msec zugrunde, so würden sich Schalleitungs-Geschwindigkeiten zwischen 500 und 833 m/sec ergeben. Es wird individuelle Unterschiede geben. Allen und Fernandez rechneten mit Geschwindigkeiten zwischen 340 m/sec (nach v. Békésy 1948) und 2000 m/sec (Schallgeschwindigkeit in Elfenbein) und schätzten den Weg zwischen beiden Ohren auf 25 cm.

Besonders das Ergebnis 3) hat die Auffassung dieser Arbeit unterstützt

In dieser Versuchsreihe war dieselbe Fusionsgrenze bestimmt worden sowohl mit wie ohne Zwischenschaltung der knöchernen Strecke zwischen beiden Ohren In dieser Reihe wurde die Zeitdifferenz mit 0 3 msec merklich kleiner gefunden als bei der Anordnung nach 1) und 2) Diese Laufzeitdifferenz von 0 3 msec paßt am ehesten zu physikalischen Messungen der Knochenleitungs Geschwindigkeit die an anderer Stelle mitgeteilt werden sollen Sie werden die Arbeitshypothese unterstützen daß beim Hören von Impulsen der verwendeten Qualität nicht ein Anstoßen von Schädel Eigenschwingungen entscheidend ist sondern daß es zur Ausbreitung von Knochenschall nach Art von Erdbebenwellen kommt

Diese Vermutung wird m E auch von dem Befund der Ergebnisse 4) und 5) erhärtet Der Hörer lateralisiert beim Weberschen Versuch mit Impulsen gegen alle Regel nicht in das Ohr dessen Gehörgang verschlossen oder dessen Schalleitung gestört ist sondern er lateralisiert stets in die Kopfseite der das Knochenschall Telefon aufliegt u U entstehen deutliche stereophone Empfindungen Bei Anregung von Eigenschwingungen bestünde für diese Beobachtung kein Anlaß Eigenschwingungen des Kopfes müssen Trägheitsbewegungen der Wassertreppen mit einem festen Phasenverhältnis zwischen beiden Schnecken bewirken Dieses ist weitgehend unabhängig vom Ansatzpunkt des Schallgebers Außerdem kann sich bei Anregung durch Eigenschwingungen keine Änderung des Phasenwinkels durch Änderung der Pulsfrequenz von 2/sec auf 100/sec ergeben Die Eigenschwingungszahl des knöchernen Schädels liegt nach v Bekesy (1948) bei 1800 Hz

Wenn das Hören von Impulsen der bezeichneten Qualität nicht durch Anregung von Eigenschwingungen zustande kommt und wenn erzwungene frequenztreue Schwingungen des Schädels als ganzes nach dem Vorhergesagten (Zeitdifferenzen) dieses Hören der Impulse nicht erklären dann erscheint die Absicht berechtigt das Wesen des Anregungsvorganges in dem Eintreffen von Kompressionswellen an den Labyrinthen zu suchen Ihre Ausbreitung an den spiraligen Labyrinthkapseln ist nicht klar zu übersehen Ob es wirklich gleichzeitig zur allseitigen Kompression eines Innenohres kommt ist nicht erwiesen sondern ist nur überschlagsmäßig angenommen worden Vielleicht liegen in diesem unübersichtlichen Feld die Schlüssel für das Verständnis der einleitend angeführten zunächst unerwarteten Knochenleitungs Schwellen verborgen

SUMMARY

In spite of the validity of modern bone conduction theories (v Bekesy Ranke) hearing by bone conduction of trains of pulses (clicks) raises new questions Significant interaural time differences have been observed by measuring the upper limit of temporal fusion of such clicks in normally hearing persons and in one case of unilateral total deafness Evidence is given that acoustic transients—applied to a mastoid bone need a considerable space of time for crossing the distance between both of the inner ears This suggestion is emphasized by the observation that bone conducted clicks (repetition rate less than 50/sec) are not lateralized according to the Weber test but that their lateralization depends on the position of the receiver on the skull

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Eingegangen Mai 196

GIORGIO FERRERI

(1893-1961)

In Memoriam

By the sudden death on July 15, 1961, of Professor Giorgio Ferreri, Director of the Otorhinolaryngologic Clinic at the University of Rome, the medical and academic world has suffered a great loss. It is an honour for me to pay tribute to the memory of a distinguished master and dear friend.

Ferreri's brilliant career was characterized by unflagging energy and enthusiasm for his special field, to which he had devoted himself exclusively since obtaining his doctor's degree in medicine and surgery in 1917 at the University of Padua. As a clinician, he was of the highest quality, with a wide experience and sympathetic understanding of his patients' needs.

His keen interest in co-ordinating the otorhinolaryngologic, oculistic and neuropathologic fields led him to take an active part in founding the Oto-Neuro-Ophthalmologic Society, of which he became the first General Secretary.

In 1930 he became Professor in charge of the Otolaryngologic Clinic at Perugia, serving there with characteristic enthusiasm and drawing freely on his scientific ability. Returning to Rome in 1931, he was appointed Head of the E.N.T. Department at the Hospital of Rome, where those friendships were formed which won him the affection and esteem of leading otorhinolaryngologists everywhere.

Ferreri resumed his academic career in 1951 as Associate Professor (subsequently Professor) in charge of the Faculty of Medicine at the University of Rome, in which post he remained until his death. As Head of this great and modern Institute, he furthered its development and made it a model of technical and organizational excellence.

Professor Ferreri actively participated at specialist meetings of the various otorhinolaryngological societies, both in Italy and abroad, and took part as docent at numerous international courses organized by the Faculty of Medicine of Paris. In addition, he was a founder member of the International Association for Otosclerosis and President of that Association's Italian committee.

Professor Ferreri's qualities as a doctor and a man made him worthy of the greatest admiration among his friends and colleagues throughout the world.

Michele Arslan

SCANDINAVIAN COURSE IN STAPES SURGERY[1]

Technique and results of the operation as demonstrated by Urpo Siirala[2]
Photographic and cinematographic equipment
Demonstration of the surgery by television

URPO SIIRALA, JAAKKO LUMIO and SAKARI SORJONEN
Helsinki, Finland

TECHNIQUE AND RESULTS

Good technique of stapes surgery is conditioned by (1) strict asepsis, (2) good anesthesia, (3) effective hemostasis, (4) wide visual exposure, (5) sufficient time, quiet surroundings and comfortable position of surgeon and patient.

The surgical technique will here be considered against the background of these prerequisites.

On the day before the operation the meatus is cleaned and a packing immersed in 1 per cent trypaflavin is inserted. Premedication consists of Atropedin 0.1 ml per 5 kg of body weight (1 ml Atropedin contains 50 mg pethidine and 0.5 mg atropine) subcutaneously one hour before operation.

Operations in the stapes can in most cases be done under local anesthesia. The majority of our cases in the Helsinki University Ear Hospital were operated on without using general anesthesia. Recently we have also had good experience with operations performed under general anesthesia. A local anesthetic (1.5 ml per cent Carbocain to which is added ½ ml of adrenalin 1/1000) is used also in cases operated under general anesthesia. Because of the relatively high adrenalin content anesthesia is induced with nitrous oxide and intravenous medication, which makes it possible to cauterize bleeding vessels. The anesthesia is continued later with fluothane when the effect of adrenalin has receded.

Hemostasis is obtained with adrenalin and carbocaine plus cauterization and, if necessary, hypotension. The hemostasis must be as effective as possible.

The surgical approach is through an endaural incision. The temporal fascia is exposed. A square piece is cut from the fascia and preserved for later closure of the oval window. The operation proceeds under the microscope. The meatal skin is dissected from the bony meatal wall up to the annulus tendineus of the tympanic membrane. To render visual exposure as wide and broad as possible the meatus is emptied by means of suction and the dorsal skin that has been freed is pressed against the anterior wall

[1] Held at the Helsinki University Oto-Laryngological Hospital, March [illegible]

[2] The technique demonstrated by Otto H. Meurman and Tauno Palva was published in *Acta Oto-Laryng.* [illegible]

The skin of the posterior meatal wall remains in this position as in the case of an empty bag the sides of which are apposed when it is compressed and its mouth closed. This procedure succeeds well if no perforation of the meatal skin has occurred. The posterior insertion of the tympanic membrane with the annulus is freed from the sulcus and the middle ear opened by pushing forward the drum and the meatal wall. Here again it can be useful to compress the meatus and clear it of air. In this manner a good view of the middle ear is obtained but as a rule the most medial portion of the posterior meatal wall must be removed for a good view of the oval window. Before this the chorda tympani must be dissected free and pushed to the side. This will mostly succeed better if the bony canal of the chorda is opened. The bony wall of the meatus should preferably be manipulated with a chisel which enables one to pick out all bone fragments more easily. The work is completed with a sharp edged gouge.

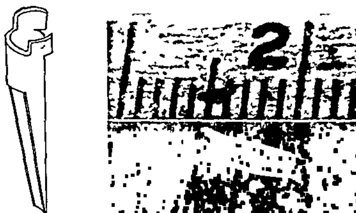
This part of the operation frequently requires a good deal of patience especially if it is necessary to remove much bone. But it is much better to spend time and care on the creation of wide and good access to the stapes and the oval window than to attempt working in too cramped a space.

At this stage of the operation we are able to check the correctness of the diagnosis. The oval and round windows are inspected and the stapes is *palpated and if diagnosis is correct the stapes is found to be more or less rigid.* This is also when the decision as to the type of stapes surgery to be used in each case must be made.

Stapedectomy is begun by dividing the stapedius tendon. This is done for example with a pointed lancet. The incudostapedial joint is then unlocked by introducing a hook under the crura the superstructure is separated from the footplate. If bleeding ensues it may be advisable at this stage of the operation to insert a small cotton pledget immersed in adrenalin and thrombin into the window niche. After a moment the cotton pledget is removed and the stapes plate can then be watched. If the mucoperiosteum is thick it is advisable to scrape the window niche free.

The plate is palpated with a thin pointed instrument so as to discover the extent of its rigidity. The stapes plate is then perforated somewhere in the central region or at the side if the plate is thinner there. Perilymph now leaks out *and the patient begins to hear better. Through the* small opening a hook is inserted under the plate which is elevated by fragmentation. At this stage it fairly often happens that blood trickles up into the window. The blood can be removed with caution using suction or a thin mop. The window is now covered with a piece of fascia which extends beyond the window margins.

A polyethylene tube is now inserted. Its lower end must stand in the centre of the fascia and its upper end be firmly fixed to the lenticular process. Generally it is not difficult to get the lower end to retain its proper position. It is much more difficult however to obtain a firm connection between the lenticular process and the polyethylene tube. After many experiments I



Figs. 1 and 2. Wing grip polyethylene tube.

have begun to use a type of polyethylene tube here termed "wing grip" design (see Fig. 1). The lower end of the tube is bevelled. Its upper end has two handle-like extensions. They enclose the lenticular process on both sides. The gaps between the "handles" have their specific functions. The lateral one is broad and deep and intended to let the lenticular process through easily when the tube is pushed in position. In the medial gap there are two flap-like extensions at the sides. These "wings" help fix the tube to the long process so that it follows the latter's vibrations. When inserting the polyethylene tube the bevelled end is first placed in the correct position in the centre of the fascia. The tube is then pushed under the long process so that the wing-like extensions are on each side of the long process and the last stage consists in pushing the upper end of the tube laterally so that the lenticular process "jumps" into the upper opening of the tube and is retained by the grip of the "wings" in the medial opening.

The mobility of the tube is checked by carefully pressing the long process. One can then also see whether the tube is well fixed to the long process and whether its movements cause mobility in the round window. The operation is now practically speaking completed. It only remains to replace the chorda, the drum membrane and the meatal skin. If ruptures have occurred in the skin or drum membrane they can be repaired with a piece of temporal fascia, which is an excellent material for the purpose.

The meatus is then packed and the wound sutured. Tampons are removed after two or three days, the sutures on the third or fourth day, which is when the patients are usually discharged. The hearing, as a rule, has markedly improved by the time the packing is removed, and improves further during the weeks immediately following.

Instead of performing a complete stapedectomy, it is possible—especially in the presence of favourable anatomic conditions—to remove only the stapes footplate and replace it by a piece of fascia. The crura of the stapes are fractured at their insertion to the plate, a perforation is made in the plate and

it is elevated in fragments. It is not necessary, although helpful, to push the crura to the side while the footplate is being removed and the fascia is pushed under the crura to seal the opened window. It is of importance that one of the crura, preferably the dorsal crus, has good contact with the fascia. Then one need not be afraid that this contact will be interrupted when the fascia shrinks as it heals later. This method guarantees that the continuity of sound will not be interrupted between the incus and the stapes. This may occur, however, between the crura and the fascia. Otherwise the operation is performed as described above. Should the hearing improvement not be lasting, the middle ear can be opened and other surgical procedures for the restoration of the continuity of sound transmission can be resorted to.

In cases in which the oval window is entirely obliterated, for instance through the footplate becoming fixed to the window margins by new bone formation, it may be safest to desist from a stapes operation and try to obtain hearing improvement by fenestration of the horizontal semicircular canal.

Most of our patients received penicillin after operation. Postoperative vertigo was slight in most cases. In some cases there have been disturbances of equilibrium during the first and second weeks, in an occasional case even longer.

The chorda was pushed aside cautiously at most of the operations. Only exceptionally was it sectioned.

Air inflation and Valsalva helped relieve obstruction in the ears blocked during the first few days after operation.

The change-over from stapes mobilization to removal of the stapes plate or fenestroplasty, as we here call the operation, took place in our hospital after careful consideration. Mobilization of the stapes, as time went on, did not fulfil our expectations, obviously due to the fact that in many cases the footplate, or what had been saved of it, was refixed by otosclerotic bone to the margins of the oval window, and the hearing deteriorated again. This showed that *better results could be expected only by using complete removal of the foot plate and sealing the wind ow with some material which cannot form osseous connections to the window margins*. Temporal fascia proved suitable for the purpose.

It seems most natural to use the stapedial crura for conducting sound from the incus to the oval window. Occasionally we found that the crura had postoperatively become attached by adhesions and grown less mobile. Because of this and the fact that it is often technically easier to perform stapedectomy than to leave one crus or both crura in place, particularly if anatomically the working conditions are unfavourable, we increasingly began to use stapedectomy, replacing the crura with a polyethylene tube. Such a tube was also used in cases where the crura appeared too short.

What I wish to emphasize especially in our technique is the *endaural incision*, which renders possible the creation of a wide field of vision. It is easy to continue the operation immediately as a fenestration if the patho-

logical changes in the oval window are too severe for operative procedures to be performed on the stapes.

The endaural incision also enables us to obtain a collapse of the soft tissues of the auditory meatus by pushing the skin of the exposed posterior meatal wall and also the posterior half of the drum forward, thus widening the visual exposure. When the entire posterior bony wall of the meatus is exposed, it is also possible to chisel away so much bone that a proper view of the oval window is obtained. In most cases, then, the chorda can be spared.

RESULTS OF OPERATION

The results shown below were obtained by analysing the first 216 cases operated upon. Hearing improved in 200 of these. In no single case did operation cause deafness. In eight cases hearing remained unchanged, and in another eight cases it deteriorated to some extent. The tables below include only those 200 cases in which hearing improvement was achieved. The first examination took place at discharge from the hospital, viz. about 4–7 days after operation. The second examination was made after three months and the third after six months. The results of operation are recorded as averages of the thresholds for the frequencies 500, 1000, 2000 and 4000 cps.

1. Average air bone gap after operation

Number of cases	200	127	38
Immediate result	16.3 db		
Result after 2–3 months		12.8 db	
Result after 5–6 months			9.1 db

Thus the result improved further as time went on and six months postoperatively the average air–bone gap was only 9.1 db.

2. Average improvement of air conduction

Number of cases	200	127	38
Immediate result	16.4 db		
Result after 2–3 months		26.0 db	
Result after 5–6 months			29.6 db

In this respect too, the result improved with time: six months after operation the average improvement by air conduction was almost 30 db.

3. Average improvement of 50% discrimination in speech audiogram

Number of cases	200	12	38
Immediate result	17.4 db		
Result after 2–3 months		27.6 db	
Result after 5–6 months			2[illegible].7 db

The speech audiogram thus also improved markedly after operation.

It is thus abundantly clear that the result of operation cannot be assessed at the time the patient is discharged from hospital, when the gain in hearing

TABLE 1. *Comparison of the results of the two operation methods*

	Type of operation	Immediate result		Alteration from first to second investigation		Alteration from second to third investigation	
		Observations	Decibels	Observations	Decibels	Observations	Decibels
Air-bone gap	Crura	122	[illegible]	83	5.3 ± 1.2	29	0.8 ± 1.1
	Polyethylene tube	78	15.5 ± 1.0	41	3.8 ± 1.0	12	0.4 ± 1.1
Improvement of air conduction	Crura	122	14.4 ± 1.1	83	8.5 ± 1.4	29	2.0 ± 1.7
	Polyethylene tube	78	17.6 ± 1.2	41	1[illegible].9 ± 1.7	12	4.6 ± 2.3
Improvement of 50% discrimination in speech audiogram	Crura	122	17.0 ± 1.1	83	8.9 ± 1.6	29	−1.0 ± 1.5
	Polyethylene tube	78	17.9 ± 1.7	41	10.2 ± 2.1	12	7.5 ± 5.0

is often fairly slight. The result improves considerably within a few weeks and it is usually maintained. The present series, however, includes so few cases followed for one year postoperatively that the permanence of the result cannot be finally evaluated here. The figures appear very promising, however.

The crura were utilized in 122 cases and a polyethylene tube in 78 cases for conducting sound into the skin graft in the oval window. The results of these two procedures are compared above. Table 1 gives the means and standard errors of the means.

Comparison shows that there is a statistically significant difference only in the immediate postoperative result as far as improvement in air conduction is concerned. Here it is seen that, applying the *T* test, the result with the polyethylene tube is on average better, the difference being slightly significant (P 0.05). In the case of air conduction the changes occurring between the first and the second follow-up examination also support such a difference.

In the present study, then, the results were slightly better with the polyethylene tube than when utilizing the crura for conducting sound from the incus to the oval window. The difference, however, is only significant as far as air conduction improvement is concerned.

Complications

Rupture of the meatal skin occurred in 20 cases. It always healed well without causing any infection or harmful scarring.

Rupture of the tympanic membrane occurred during dissection of the drum margins in a total of 12 patients, in four of whom the same ear had previously been operated on.

The perforation was always small and generally close to the drum margin

All these ruptures healed without being complicated by infection and in none of the cases was a perforation visible at discharge

Facial paralysis developed in two patients The paralysis was diagnosed in one of the cases six months after operation and there was complete spontaneous cure within the next three months In the other case the area of the oval window was very firmly fixed by osseous tissue and so anatomical orientation was extremely difficult The nerve was damaged in drilling and lost function completely As no signs of restored nerve function appeared during two months a neurorrhaphy was performed in the same ear This helped to restore the function

Infection appeared later when the patients were at home in five ears Examination showed otitis externa in one case it healed rapidly by treatment with ear drops only In four cases there was otitis media which was treated with antibiotics Discharge ceased in all these cases within a week In two patients the perforation closed immediately In two however there was still a small perforation a few weeks later but spontaneous closure occurred in both

Severe vertigo was complained of by four patients In two of these cases vertigo first appeared during the operation and did not disappear until several weeks later Electronystagmography showed diminished function but not total dysfunction of the vestibular apparatus The vertigo in one case started four days after operation and spontaneous nystagmus to the contralateral side was diagnosed at the same time This patient received antibiotic therapy and was free of symptoms in five days The fourth case will be described here in greater detail The patient was a man aged 28 on whom fenestroplasty was performed in both ears at an interval of 14 days He was discharged at the usual time and there was a satisfactory hearing improvement Two months later he became ill with a mildly acute respiratory infection When blowing his nose he felt giddy and one ear became suddenly deaf He at once came to the hospital and was admitted to the ward complaining of severe vertigo No spontaneous nystagmus was noted One ear was completely deaf The patient was treated with antibiotics but two days later electronystagmography showed a weak but distinct spontaneous nystagmus to the side of the hearing ear Tympanotomy was at once performed and revealed numerous adhesions and viscid secretion in the middle ear The middle ear mucosa was thick and reddened The polyethylene tube was firmly in position between the incus and the graft and there was no visible perforation in the latter The middle ear was cleaned by suction and the polyethylene tube was left in place

Vertigo and spontaneous nystagmus now disappeared in a week but follow up examination three months later showed a deaf ear and absence of vestibular response

Thus there were only two major complications of fenestroplasty a case of traumatic facial paralysis which was cured by neurorrhaphy and a case of complete loss of labyrinthine function in an operated ear occurring two months postoperatively in connection with infection

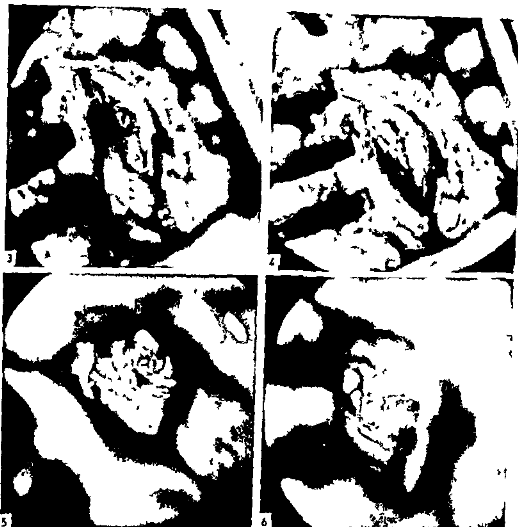


Fig. 3. The posterior insertion of the tympanic membrane is freed. The mucoperiosteum of the tympanum is seen from below.
Fig. 4. The most medial portion of the posterior meatal wall must be removed for a good view of the oval window.
Fig. 5. View of the middle ear after it has been opened by pushing forward the drum and the skin of the posterior meatal wall.
Fig. 6. The stapes plate has been perforated and fractured.

Photography, cinematography and demonstration by television

Photography, cinematography and corresponding TV demonstrations of operations for improvement of hearing and other procedures on the auditory organs performed through the meatus place considerable technical demands on the microscopic and photographic equipment used. Unfortunately the manufactured equipment available on the market does not fulfil these requirements satisfactorily. Available operation microscopes, it is true, are mostly excellent from the point of view of the operating surgeon, yet in their

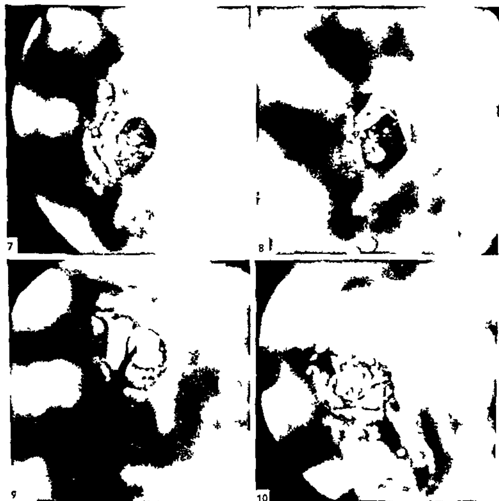


Fig. 7. Most of the stapes plate has been removed.
Fig. 8. The oval window when wholly opened.
Fig. 9. The window is covered with a piece of fascia temporalis.
Fig. 10. The "wing grip" polyethylene tubing in place.

construction the needs of photography have usually received no attention and if so the auxiliary apparatus does not comply with even modest requirements.

Because of this, experiments have been conducted by the Department of Otolaryngology of the University Central Hospital in collaboration with the Institute of Photography of the University of Helsinki with the aim of developing a serviceable photographic set-up for the purpose. The Zeiss operation microscope was used. The requirements to be fulfilled by a microscope suitable for photographic methods were formulated as follows:

1. Utilization of all magnifications of the microscope must be possible also when photographing.

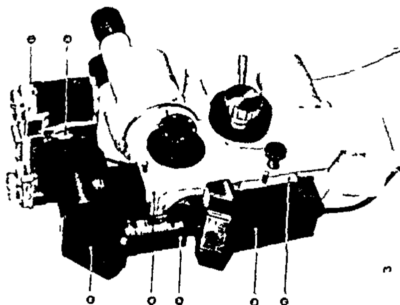


Fig. 11. The combined flash light and camera set up manufactured by Zeiss.

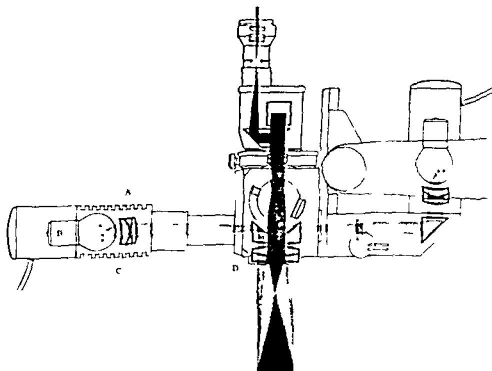


Fig. 12. The modifications made in the Zeiss operation microscope.



Fig. 13. The additional lamp housing was constructed of aluminium and provided with a cooling system.

2. Illumination of the object to be photographed must be sufficient up to a speed of 24 exp./sec. also when using colour reversal films.

3. The required additional illumination must be carried to the object as close as possible to the optical axis of the microscope in order to minimize the loss of illumination in the metal walls and to ensure shadowless and even illumination of the object.

4. Illumination must not cause excessive warming of the object.

5. Reflections occurring on the edges of the field to be photographed, e.g. those due to shine on the instruments, which are very troublesome especially when using a TV camera, must be eliminated as far as possible by using the iris diaphragm of the camera lens. In other words the set up must be devised so as to enable a lens to be used in the camera, though the use of the camera lens has its drawbacks.

6. It must be possible to attach to the microscope easily and with sufficient accuracy a 35 mm still camera, a 16 mm ciné camera, or a TV camera.

7. The microscope with its cameras must be balanced in such a way that it is easily movable on its support and remains in position without complicated locking procedures.

8. The surgeon must have at his disposal both the oculars of the microscope during exposure too, to ensure a three dimensional view of the object throughout the operation.

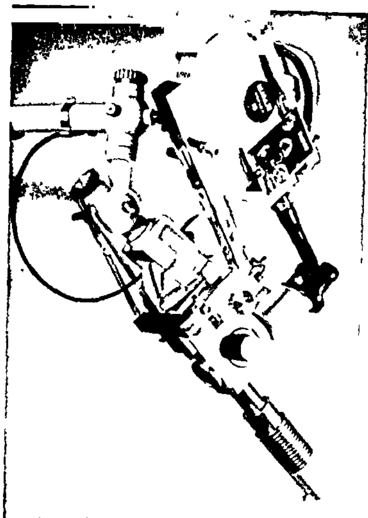


FIG. 14. The stand of the TV and camera was made of steel and later chromium plated. Balancing was achieved with springs.

9. The required accessory apparatus and the photography itself should interfere with the surgeon's work to the least possible extent.

For the early experiments we used the equipment already available at the Ear Hospital. The combined flash light and camera set up manufactured by Zeiss (Fig. 11) works well, but gives too low magnification, and in addition the directing of illumination is unsatisfactory. This apparatus is of no help when using cinematography and TV methods. We also had at our disposal an accessory photographic set up constructed in the USA by Storz Instrument Company for the Zeiss operation microscope; this was intended for cinematography and thus was assumed to be serviceable for TV methods. The equipment, however, proved practically speaking useless: the intensity of illumination was entirely inadequate for colour exposures, and mounting of the cameras was very difficult and time consuming; the exposures also had to be made without a camera lens and so possibilities of eliminating unwanted reflections

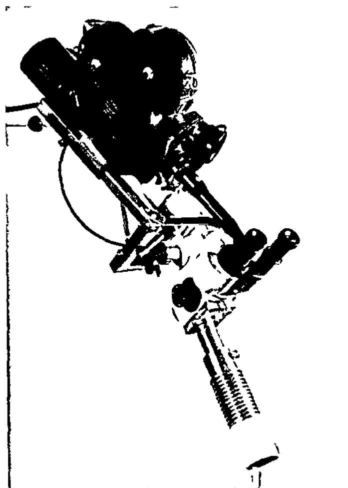


Fig. 13. The equipment for cinematography

were lacking. The intensity of illumination might have been slightly increased by changing the semitransparent mirror placed in the ocular, but even this would not have given satisfactory results.

On the basis of the experiments, the modifications shown in the diagram (Fig. 12) were made in the Zeiss operation microscope. To obtain sufficiently powerful illumination of the object, a second lamp house (A) was constructed in which a low voltage lamp (B) employing excess voltage during exposure was used similarly as in the original source of illumination. The light is directed to the object by means of condenser lenses (C) and a prism (D), in such a way that its path and that of the original illumination are symmetrically situated in relation to the optical axis of the microscope. The following Zeiss spare parts were utilized:

Condenser	303[illegible] 17, 303[illegible] 105, 106, 201, 202 and 203
Prism	[illegible] 3[illegible] 115, 116, 117, 118 and 119
Lamp (6 V, 5 W)	[illegible]018[illegible]

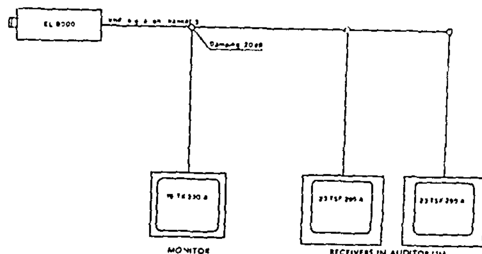


Fig. 16. Standard Philips sets were used for the TV demonstrations.

The additional lamp housing was constructed of aluminium and provided with a cooling system; the stands of the cameras were made of steel and later chromium plated. Balancing was achieved with springs (Figs. 13–15).

The exposure is made through a Zeiss lateral ocular (10 ×) inserted into one of the ocular tubes. The following cameras and films were used:

Photography: Bellina Reflex, lens Xenon 2.0/50 mm, Kodak close up lenses N132 and N113, Agfacolor CN20 (80 ASA) and High Speed Ektachrome Type B (125 ASA).
Cinematography: 16 mm Arriflex and 16 mm Bolex Weko (exposure controlled with sector diaphragm).
TV demonstrations: Philips Compact Television Camera EL 8000.

The auxiliary photographic set-up devised by us for the Zeiss operation microscope has been in routine use for several months and has proved fully satisfactory. Illumination has been sufficient when using the above mentioned films and there have been no harmful heat effects. The equipment is fairly easy to operate and exposure interferes little, if at all, with the surgeon's work. For reasons of economy we used for the TV demonstrations the standard Philips sets (Fig. 16), having normally a resolving power of 4.5 MHz/3 db and only a VHF input. Since a Compact EL 8000 camera has also a video output, it would serve our purposes better to use a Video monitor set; the resolving power would then improve so as to correspond to the band width (5.5 MHz) of the video signal of the camera.

Seeing that, at least in Finland, the cost of the color film currently used by us for cinematography is unreasonably high as compared with the price of slower films, e.g. Kodachrome, and that development in the USA causes awkward delays, we are trying at present to increase the intensity of illumination further. Using low voltage lamps it is scarcely possible to increase illumination without getting at the same time harmful heat effects, but the solution

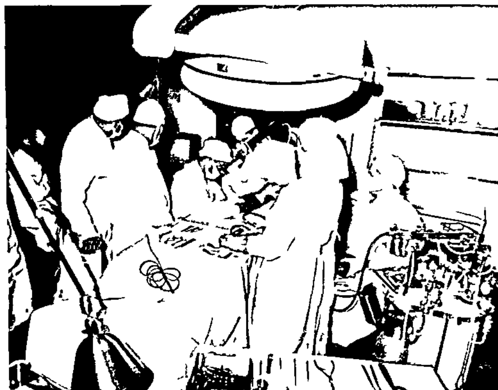


FIG 17 Demonstration of stapes surgery by television

seems to lie in the use of a stroboflash or pulse lamp synchronized with the camera Our experiments however are still in the early stages and we shall return to this matter in a later article

SUMMARY AND CONCLUSIONS

A total of 216 otosclerotic ears have been operated upon by the fenestroplasty method removing the stapes footplate and using either the crura or a polyethylene tube to conduct sound from the long process of the incus to the oval window Hearing improved in 200 cases remained unchanged in eight cases and deteriorated slightly in eight No single ear became deaf as a result of the operation

Better results of stapes surgery can be expected by using complete removal of the footplate and sealing of the oval window with some material which cannot form osseous connections to the window margins Temporal fascia has proved suitable for the purpose It seems most natural to use the stapedial crura for conducting sound from the incus to the oval window However in our hands a polyethylene tube has given a slightly better average improvement of hearing It is essential for a good result that the polyethylene tube

rem ins firmly in position The wing grip design has proved advant geous from this point of view

The auxiliary photographic set up devised by us for the Zeiss oper ation microscope is described It is very helpful for demonstr tions of surgery under a microscope The endaural incision used in these oper tions renders possible the cre tion of a wide field of vision enabling us to obtain a collapse of the auditory me tus by pushing its posterior w ll and lso the posterior half of the drum forw rd thus widening the visual exposure and making the oper ti n itself and also its demonstrati n by television easier

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CHOLINESTERASE AND ITS RELATION TO THE NERVE ENDINGS IN THE INNER EAR

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The inner ear sensory epithelia in the guinea pig were stained with Holmstedt's modification of Koelle's thiocholine method for localization of cholinesterase activity and the staining reaction was studied with light and electron microscopy. Acetylcholinesterase activity was found as follows in specimens treated with the butyrylcholinesterase inhibitor Mipafox:

A. In the internal spiral bundle of all turns in the cochlea.

B. In nerve endings belonging to all rows of external hair cells in the basal coil.

C. In the nerve ending region of the two innermost rows of the external hair cells in the second and third turns and only in the inner row of outer hair cells in the apical turn.

There was a close relation between the staining reaction and the localization of large granulated nerve endings in the cochlea.

In the vestibular sensory epithelia the precipitate caused by staining reation was found in the granulated nerve endings on the outside of the nerve chalices and at the bottom of the hair cells type II.

When acetylcholinesterase was inhibited, staining occurred with the solutions for demonstration of butyrylcholinesterase in the stria vascularis and diffusely in the cristae with most intense staining in the planum semilunatum.

The significance of the result is discussed.

The description of efferent nerve fibres going from the superior olivary complex to the cochlea (Rasmussen 1946, 1953, Fernandez 1951) and the electron microscopic demonstration of two morphologically different types of nerve endings in the cochlea (Engström & Wersäll 1953, 1958, Engström & Sjöstrand 1954) and the vestibular sensory epithelia (Wersäll 1954, 1956, Engström 1958) clearly demonstrated the complexity of the innervation of the inner ear. The significance of different nerve endings has been discussed by Wersäll (1956), Spoendlin (1957), Engström & Wersäll (1958), Engström (1958), Smith (1961), Smith & Sjöstrand (1961) and Kimura & Wersäll (1962).

[1] Presented at the Seventh International Congress of Otolaryngology, July [illegible] 1961.

[2] Much of this study was done during the tenure of a special fellowship BT 648 from the National Institute of Neurological Diseases and Blindness.

[3] Work supported through research grants from the Swedish Medical Research Council, the Therese and Johan Andersson Minnesfond and the National Institutes of Health.

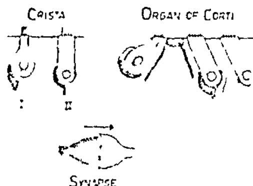


Fig. 1. Schematic drawing showing localization of granulated nerve endings in the inner ear.

Searching for a method for demonstration of the efferent nerve endings in the cochlea Churchill, Schuknecht & Doran (1956) and Schuknecht, Churchill & Doran (1959) studied the localization of cholinesterase activity in the organ of Corti in cats before and after cutting of the olivo cochlear bundle. Dohlman & Änggård (1958) and Dohlman, Farkashidy & Salonna (1958) showed cholinesterase activity in the vestibular sensory epithelia of pigeons and guinea pigs. Ireland & Farkashidy (1961) suggested that their method demonstrated the existence of efferent fibres in the vestibular sense organs. Vinnikov & Titova (1958) showed a decrease of cholinesterase activity in the cochlea after stimulation with loud tones. Wersäll, Hilding & Lundquist (1961) demonstrated a correlation between the large richly granulated nerve endings in the cochlea and acetylcholinesterase working with Holmstedt's modification of Koelle's thiocholine method in guinea pigs. This method is more specific than the original Koelle and Friedenwald method which was

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Figs. 2–10. Light micrographs demonstrating the localization of cholinesterase activity in the inner ear with the thiocholine method.

Fig. 2. *Acetylcholinesterase activity in the crista ampullaris. The precipitate caused by the staining reaction is found mainly basally in the sensory epithelium.*

Fig. 3. Butyrylcholinesterase activity in the crista ampullaris. The precipitate is spread over the whole crista but the main activity is found in the area of the secretory epithelium on the sides of the crista.

Fig. 4. Acetylcholinesterase activity, longitudinal section.

Fig. 5. Butyrylcholinesterase activity in the crista, longitudinal section. Observe the activity in the planum semilunatum and the cupula.

Fig. 6. *Control specimen.*

Fig. 7. In the second coil in the cochlea first and second external hair cell rows show activity in their nerve ending regions.

Fig. 8. In the basal coil intense staining is found under all external hair cells as well as internal hair cells.

Fig. 9. Butyrylcholinesterase activity was demonstrated mainly in the stria vascularis and in the region of the spiral prominence.

Fig. 10. Control specimen.



2



3



4



5



6



7



8



9



1



Fig. 11. Survey picture from sensory epithelium in the crista ampullaris demonstrating the two types of sensory cells.



Fig. 12. Survey picture from the crista ampullaris showing the localization of the precipitate formed by the staining for demonstration of acetylcholinesterase. Cf. Fig. 2.

used by Churchill, Schuknecht & Doran in their first paper. In the present study we tried to find out whether a correlation between one type of nerve endings and acetylcholinesterase could be demonstrated throughout the inner ear.

MATERIAL AND METHODS

Healthy albino guinea pigs weighing about 250 g with normal Preyer reflex were selected for the study. The animals were decapitated, the temporal bones removed and the bone encasing the cochlea and the vestibule was removed. Reissner's membrane was torn open in all cochlear coils to permit quick penetration of reagents.

Each specimen was passed through the appropriate solutions in one of the stages in Holmstedt's (1957) series. The inhibitors and substrates were the same as in Holmstedt's procedure (Table 1). Only the mixtures A, B, D, E and G in the table were used.

After passing through the incubation solutions some specimens were fixed in 10 % buffered formol, others in 1 % buffered osmium tetroxide solution (Rhodin 1954). The ampullae of the semicircular canals were dissected out and these, as well as the whole cochlea, were dehydrated in alcohols and embedded in butylmethacrylate with 0.2 % benzylperoxide as a catalyst.

After polymerization of the *plastic the cochleas were further dissected*

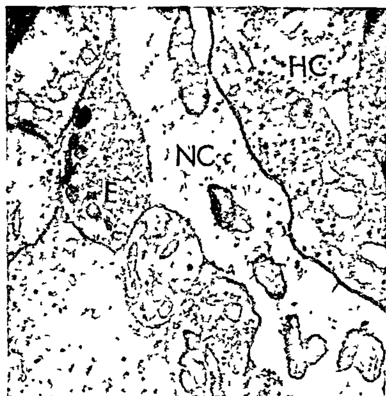


Fig. 13. Granulated nerve endings (*E*) on the base of a nerve chalice (*NC*) and their relation to the hair cell type I (*HC*).

They were split axially and each turn separated and remounted. In this way a complete picture of the whole cochlea was achieved. Survey sections were cut for light microscopy free hand with a razor blade. Some were photographed with a Zeiss 35 mm photomicroscope. Thin sections were cut on an Ultratome and studied with a Siemens Elmiskop I.

Table 1

Specimen	Treatment		Cholinesterase visualized
	Inhibitor	Substrate	
A	—		Acetylcholinesterase (AcChE) + Butyrylcholinesterase (BuChE)
B	Mipafox	Acetylthiocholine	AcChE
C	BW		BuChE
D	Mipafox + BW		—
E			BuChE
F	Mipafox	Butyrylthiocholine	
G	BW		BuChE



Fig. 11. High magnification of Fig. 12 demonstrating the localization of the precipitate close to the granulated nerve ending region at the base of a nerve chalice on a type I hair cell (I) and in a nerve ending on a type II hair cell (II).

RESULTS

Specimens incubated with Mipafox as an inhibitor for butyryl cholinesterase demonstrating localization of acetylcholinesterase

Intense staining was seen in the light microscopic studies of the cochlea in the nerve ending region under all external hair cells and in the internal spiral bundle in the basal turn. The second turn showed less staining under the outermost row of external hair cells but was otherwise stained like the basal coil. The third turn showed staining in the internal spiral bundle, intense staining under the first external hair cell row and faint staining under the second row. The apical coil showed faint staining in the internal spiral bundle, intense staining under the first row of external hair cells and practically no staining under the other hair cells (Figs. 7, 8).

In the electron microscope a black precipitate was observed in close relation to the internal spiral bundle and in and around some of the nerve endings under the external hair cells with the same localization in the various turns in the cochlea as discussed above for the light microscopic pictures. Some of the precipitate was found attached to mitochondria in the nerve endings. A few granules were also found on the pillars. The localization of the staining in the cochlea was the same as that of the large granulated nerve endings (Fig. 16).

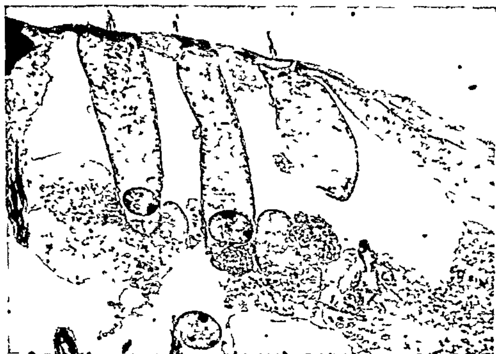


Fig 15 External hair cells from the second coil in the organ of Corti No staining

The light microscopic studies showed a very consistent localization of the stain in the lower third of the epithelium in the vestibular sensory epithelia In the electron microscope a black precipitate was found in the small granulated nerve endings at the bottom of the type II hair cells (Wersall 1956) and in the nerve endings on the outside of the nerve chalices of the type I cell (Wersall 1956 Engstrom 1958) (Figs 2 4 12 14)

Specimen incubated with BW c31 as inhibitor for acetylcholinesterase demonstrating butyrylcholinesterase

The cochlear specimens from this group were stained only in the areas of the stria vascularis with the most intense staining found around the spiral vessel The cristae ampullaris were more diffusely stained with the most intense staining in the planum semilunatum (Figs 3 5 9)

Controls

No staining was found in the control specimens

DISCUSSION AND CONCLUSION

Cholinesterase activity in the organ of Corti in cats was demonstrated by Churchill Schuknecht & Doran (1956) with Koelle & Friedenwald's (1949) thiocholine method They found acetylcholinesterase activity in the internal spiral bundle and below the external hair cells with more staining

in the basal coil than in the apical coils. When the efferent fibres in the crossed olivo-cochlear bundle were cut most of the activity disappeared (Schuknecht, Churchill & Doran 1959). Koelle & Friedenwald's original method showed many diffusion artifacts. In the present study we used the Holmstedt method in which the diffusion artifacts have been reduced. The localization of the staining found in the present study agrees with the reported results in the cat. We could also correlate the staining with the localization of the large granulated nerve endings in the organ of Corti and the internal spiral fibres (Wersäll, Hilding & Lundquist 1961). Rossi (1961) demonstrated acetylcholinesterase activity in the guinea pig fetus intraganglionic spiral bundle in the area below the external hair cells and found activity following the outgrowth of the nerve fibres in the intraganglionic bundle.

These findings all support the suggestion by Schuknecht *et al.* (1959) that the efferent nerve fibres in the olivo-cochlear bundle have high acetylcholinesterase activity. Pronounced acetylcholinesterase activity is usually found in relation to cholinergic fibres.

Stimulation of crossed efferent nerve fibres in the olivo-cochlear bundle has been shown to increase the cochlear microphonic in the opposite ear (Fex 1959) and diminish the action potential (Galambos 1956) as well as resting activity and evoked activity in the primary auditory neurons (Ruben 1960, Fex 1962). Desmedt & Monaco (1961) found that the effect of the efferent fibres was inhibited by strychnine but uninfluenced by the cholinesterase inhibitor eserin. The degree of inhibition of the esterase was however not controlled. The nature of actual transmitter substance at the endings of the efferent fibres of the olivo-cochlear bundle is still unknown. Its identity will not be fully proven until a transmitter substance can be demonstrated in the nerve ending region after stimulation of the efferent fibres.

As we have not yet cut the efferent fibres in the guinea pig and studied the relation between degenerated nerve fibres and cholinesterase activity the final proof is still missing that the acetylcholinesterase activity is entirely correlated to efferent nerve endings. Our findings in the present paper, however, support the assumption originally proposed by Engström (1958) and Engström & Wersäll (1958) and discussed by Spoendlin (1957) and Smith & Sjöstrand (1962) and finally proven by Kimura & Wersäll (1962) that there are two separate systems of nerve fibres and nerve endings in the guinea pig cochlea with different morphology and different pharmacological properties (Figs. 13–17).

From a functional standpoint it is interesting that all the external rows of hair cells in the basal coil are predominantly innervated by large granulated nerve endings with intense acetylcholinesterase activity, whereas this activity as well as the number of large nerve endings decreases apically so that in the apical coil only the innermost row shows activity. Smith & Sjöstrand (1961) demonstrated what they considered to be a type of nerve ending on the outside of small endings in the outermost rows in the apical coils in the cochlea. We have no data concerning acetylcholinesterase activity on such endings.



Fig. 16. Dark staining of the nerve ending region below two hair cells in the second coil of the organ of Corti demonstrating localization of acetylcholinesterase marked by arrow.

In the vestibular sensory epithelia Wersäll (1956) described granulated nerve endings on the cylindrical type II hair cells and non granulated nerve endings forming large nerve chalices around the type I hair cells and some small nerve endings on the type II hair cells. Engström (1958) found that

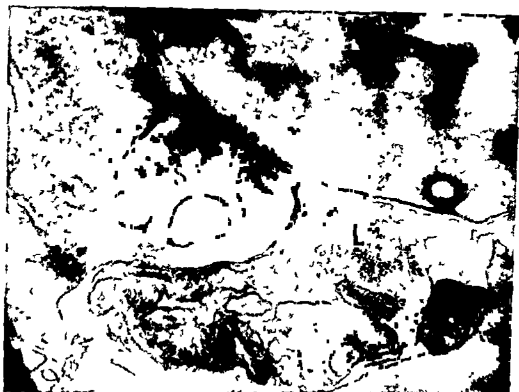


Fig. 17. Large granulated nerve ending (I) and small ending at the bottom of external hair cell in the second coil. No staining.

granulated nerve endings were found even on the outside of the nerve chalice. Thus all sensory cells are innervated by both types of nerve endings.

The light microscopic picture in the present work confirms Dohlman's and co-workers' findings that cholinesterase activity is found basally in the vestibular sensory epithelia. With the electron microscope the precipitate formed by the reaction could be localized to the granulated fibres on the nerve chalices and at the bottom of the hair cell type II. The nerve chalices, however, showed no activity (Figs. 11–14).

This confirms Wersäll's (1956) and Engström's (1958) suggestion that granulated and non-granulated nerve endings are different in nature. The physiological significance of their function is, however, still more obscure in the vestibular epithelia than in the organ of Corti. Petroff (1954) and Gacek (1959, 1960) have demonstrated a small number of efferent nerve fibres in the vestibular nerve, but their relation to the hair cells is not known. We can only suggest that the non-granulated nerve fibres are afferent. The granulated nerve fibres might either be efferent fibres coming from the vestibular nuclei in the brainstem, returning collaterals from efferent fibres or afferent nerve fibres with a function different from the non-granulated fibres. Further experiments with division of the efferent and afferent fibres will be of great interest.

Butyrylcholinesterase activity in the guinea pig labyrinth is related mainly to the secretory areas that is the stria vascularis and the planum semilunatum Other investigators (Taylor 1958) have shown that non specific cholinesterase is found in secretory epithelium cells elsewhere in the body

Since cholinesterase is inhibited by fixation it seems desirable to use unfixed tissue in studying its localization in order to get reliable and reproducible results This will cause rather large morphological changes in the specimens As pointed out by Holmstedt & Sjoqvist (1961) all stages in the procedure causing a redistribution of the precipitate should be avoided In the present paper the specimens were fixed in osmium tetroxide after the incubation in order to give a better preservation and contrast in the specimens for the electron microscopic studies A control with comparison of specimens fixed in formol instead of osmium tetroxide showed however an identical distribution by light microscopy We thus consider it justified to regard the diffusion artefacts caused by redistribution of the precipitate which might appear during the osmium fixation as small As it is impossible in the light microscope with normal technique to differentiate white between the various types of cells and endings in the vestibular epithelia we feel justified in presenting the results achieved with this rather crude method for electron microscopy for the correlation between different nerve endings and cholinesterase activity The method is not ideal for studies at the subcellar level because of large granular sizes and shrinkage artefacts but is a well controlled method for studies of the cholinesterase activity at the cellular level

Other methods for cholinesterase localization have been used for electron microscopy We found that the Lehrer Ornstein (1959) method produced considerable non specific staining in the ear

ACKNOWLEDGMENTS

We want to express our sincere gratitude to associate professor Bo Holmstedt and Doctor Folke Sjoqvist Department of Pharmacology Karolinska Institutet for helpful advice and criticism

ZUSAMMENFASSUNG

Die Sinnesepithele des Innenohrs des Meerschweinchens wurden mit Holmstedts Modifikation von Koelles Thiocholinmethode für die Lokalisierung von der Cholinesterase Aktivitat gefarbt und die Einwirkung der Farbung wurde mit Licht und Elektronenmikroskopie studiert Acetylcholinesterase Aktivitat wurde in Preparaten gefunden die mit Mipafox als spezifischer Hemmer fur Butyrylcholinesterase mit folgender Verteilung behandelt wurden

A In den inneren Spiralenbundeln von allen Windungen der Cochlea

B Unter allen Reihen von ausseren Haarzellen in der Basalwindung

C In der Nervenen lungsregion in den zwei inneren Reihen der ausseren Haarzellen in den zweiten und dritten Windungen und nur in der inneren Reihe der ausseren Haarzellen in der apikalen Windung

Es gab eine deutliche Beziehung zwischen der Farbungsreaktion und der Verteilung von grossen granulierten Nervendungen in der Schnecke.

In den vestibulären Sinnesepithelien wurde das Präzipitat, das von der Farbungsreaktion bewirkt worden war, in den granulierten Nervenendungen ausserhalb der Nervenkelche und auf dem unteren Ende der Haarzellen von Typ II gefunden.

Wenn Acetylcholinesterase gehemmt wurde, konnte man Butyrylcholinesterase in Stria vascularis der Schnecke und in Planum semilunatum der Crista ampullaris demonstrieren.

Die Bedeutung des Resultats wird diskutiert.

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UNILATERAL HYPERPLASIA OF THE MANDIBULAR CONDYLAR PROCESS

Surgical and Bite-correcting Treatment of a Case

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About 60 cases of one-sided enlargement of the condyloid process with accompanying deformation of the lower jaw were earlier described as arthritis, chondrome, osteochondrome, etc. Later (Rushton 1945, 1946) a disturbance of the growth was recognized as being the cause of this condition and named hyperplasia.

The authors have described such a case: a 36-year-old woman who from the age of 15 years experienced slight pain in the region of the left jaw joint and a slight hindrance in opening the mouth. In a later phase there was also a considerable enlargement of the condyle developing by degrees and a deviation of the lower jaw.

The condyle has been resected and the bite corrected with good result. The histological examination showed the presence of a typical growth zone.

A unilateral enlargement of the mandibular head with accompanying change of form of the lower jaw is a relatively rare phenomenon. In the literature about 60 cases have been described and given different names, which shows an obscurity in the question of etiology. Adams (1873), who first wrote of the condition, described it as a manifestation of rheumatoid arthritis. Von Eiselsberg (1906) and Hofer (1922) gave it the same description. However, later writers such as *Dufourmentel (1927)* supposed that the suggested arthritic changes are secondary to a condyle deformity of another etiology. Kinthal & Harkins (1938) considered the histological picture to show hypertrophy associated with the chondrome. Worman *et al.* (1946) and Oehlecker (1936) considered the diagnosis of osteoma to be justified without, however, giving an account of any histological examination. *Gruca & Meisels (1926) and Pichler (1948) described* the condition as "overgrowth" or "abnormal growth", an opinion that Rushton (1946) convincingly documented. In later literature (Wang, Nerderud & Lossius 1948, Gottlieb 1951, Berry 1958, Thompson 1961) this opinion has been accepted as the most probable one and the enlargement of the head named hyperplasia. By this is meant the result of a quickened or resumed activity of the condylar

growth zone (Rushton 1946) How this activity originates is unknown A comparison can be made between certain cartilage preformed exostoses of the long bones (Rushton 1945–46) and osteochondrome of the coronoid process (Lebo 1961)

Hyperplasia of the mandibular condyloid has been observed between the ages of 15 and 30 years and thus some cases have been observed after normal growth ceased The condition develops very slowly An articular ache generally exists as well as a hindrance in the opening of the mouth although to a surprisingly small extent A deviation of the jaw gradually appears the shape of the lower jaw is changed in such a manner that the ramus is elongated while the angle region drops and the lower jaw pushes forward and becomes asymmetrical In addition a malocclusion of the teeth occurs especially along the affected side

A conservative treatment of the anomaly by grinding and prosthetic *building up of the bite can be justified in an early phase when there is less deformity of the lower jaw with consideration of the possibility of a complete* check in the process In a later phase with a great change in position of the lower jaw and a present progression a resection of the enlarged condyle is indicated The operation which was first performed by Humphry in 1856 gives a very satisfactory result both aesthetically and functionally Certain corrections of the deformed bite however have to be made after the operation

Case A G female b 24 6 191[illegible]

At about 15 17 years of age pains were felt in the left jaw on opening the mouth and in the cold The lower jaw grew out more on the same side and the teeth did not contact with each other A number of grindings of the bite were made but only with a temporary result A bridge prothesis was later built up on the left side to correct the bite

Examination Before the Operation

The lower jaw deviated to the right and the angled region on the left side lay essentially lower than that on the right (Fig 1) The distance from the upper edge of the joint head to the angle measured up to about 9 cm on the left side and 6 cm on the right On opening the mouth both condyles moved forward The left condyloid process could be seen and felt considerably driven up and was of a bone hard consistency There was no tenderness and no swollen soft parts were visible In the upper jaw there was a remaining bite of 7 + [illegible] + — + 3 + [illegible] in the lower jaw [illegible] There was a bridge [illegible] The crowns [illegible] 6 had been built up to about double the height of the teeth [illegible] to make contact The teeth on the right side were ground down considerably On biting the contact was [illegible] 6 to [illegible] An earlier occurring space between the left side row of teeth had thus been corrected with grinding and bridge construction



Fig 1 Before operation the patient showed marked asymmetry of the face with deviation to the right

An X ray examination showed that the left ramus was considerably longer than that on the right (Fig 2) The left condyle was enlarged (Fig 3) and showed a fine mesh bone The head seemed to be surrounded by a thin compact layer

Considering the facial deformity existence of pain on opening the mouth and ache along the left jaw region the patient's age and the evident progres



Fig 2 Tracing of profile roentgenogram proof for operation showing the increased height of the left ramus



FIG 3 Roentgenogram of the enlarged condyle Note the large mandibular forsa

sion a surgical jaw orthopaedic treatment was considered to be indicated and this was performed in the following way

Preoperative Treatment

The bridge +3+4 +5 6 was removed In a so called analyser (Hillerstrom & Nyquist 1954) a model planning was made of the lower jaw movements at the operation Cap splints were made in the planned position on models of the jaws for the immobilization of the lower jaw after the operation

The Operation

The area of the jaw joint was exposed by an angled incision (Ascharst) The joint head being enlarged to a high degree was easily accessible The capsule was thin the lateral ligament spread out and thinned The jaw was opened at the joint below the disk There was no visible fluid in the joint The collum was sawn through at the level of the mandibular notch and then the condyloid process was mobilized and removed The enlarged articular disk which was whole though very thin in part was completely removed The upper cavity of the joint was also free of visible fluid Fascia ligament and capsule were stitched with catgut the skin with silk

Postoperative Treatment

The lower jaw was immobilized in the planned position by steel ligatures between cap splints in the upper and lower jaw After six days the steel

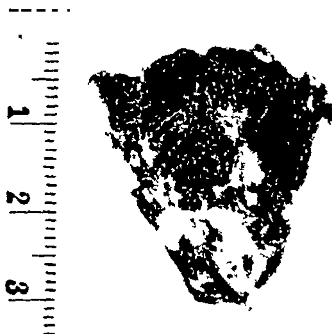


Fig. 3. The removed left condyle seen from the lateral side.

ligatures were replaced by rubber ligatures, which allowed a slight movement of the lower jaw, and after opening of the mouth conducted the lower jaw back to the planned occlusion position. After four weeks the cap splints were removed. Slight adjustment of the lower jaw position was brought about by occlusal grinding of the teeth and a temporary bridge was made. Ten months later a permanent bridge was made, which extended to +5 + +3 + 2 + 1 + + 1, and slight occlusion adjustments were made by grinding of the bite.

Operative Preparations

The mandibular head and mandibular collum were changed to a cone shape towards the joint planed formation 3 cm in length (Fig. 4). The surface of the joint was covered by a fibrous tissue layer and was 2 × 3 cm in size.

Vertical cuts through the head of the joint showed a picture to a high degree reminiscent of the state in a growing joint head. Under the fibrous cartilage surface of the joint there was a precartilaginous substance and, under this, hyaline cartilage which in a lower layer had undergone calcification.

After tissue cultivation in the presence of radioactive sulphate (S^{35}) a cellular uptake of the isotope in the cells of the hyaline cartilage was observed. The cartilage activity was essentially higher in the back, most markedly enlarged part of the joint head than in the front. Examination of the sulphate uptake is shown in a separate work.



FIG 5 Four months after operation the patient showed a near enough symmetrical face

RESULT

On examination 14 months after the operation the asymmetry of the face had disappeared (Fig 5) the occlusion after correction of the bite was good and the opening of the mouth without restriction Slight pain on opening the mouth and an occasional slight ache in the region of the right jaw joint dur ing the last month were the negative elements in an otherwise aesthetic and functionally satisfying result

ZUSAMMENFASSUNG

Etwas mehr als 60 Fälle von einseitiger Vergrosserung des Proc condyloideus und daraus resultierender Unterkieferdeformität sind in der älteren Literatur als Arthritis Chondrom, Osteochondrom usw beschrieben Später nahm man (Rushton 1946) eine Entwicklungsstörung als Ursache dieses Zustandes an und bezeichnete dies als Hyperplasie Die Verfasser beschreiben einen solchen Fall Es handelt sich um eine 36jährige Frau, die seit dem fünfzehnten Lebensjahr leichte Kiefergelenksch merzen mit einem unbedeutenden Öffnungsdefekt gehabt hat Später entwickelte sich allmählich eine Deviation des Unterkeifers auf Grund einer beträchtlichen Ver grosserung des einen Unterkieferkondyls Der Gelenkfortsatz wurde reseriert und der Biss mit gutem Resultat korrigiert Die histologische Untersuchung des Präparates zeigte u a das Vorkommen einer typischen Wachstumszone

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VERGRÖSSERUNG DER SCHALLSCHNELLE DURCH PLASTISCHE DECKUNG DER OVALEN FENSTERNISCHE, ZUGLEICH EIN BEITRAG ZUR FRAGE DER SCHALLDRUCKDIFFERENZ

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Vergrosserung der Schallschnelle durch plastische Deckung der ovalen Fensternische, zugleich ein Beitrag zur Frage der Schalldruckdifferenz

Dennhardt veroffentlichte am 25 Sept 1955 (HNO Wegweiser 31 1 56 Heft 8) die erste plastische Deckung des ovalen Fensters (der ovalen Fensternische) nach Stapesextraktion

Der erstaunliche Horgewinn blieb weitgehend konstant und konnte nach fast sechs Jahren auf dem 7 Internat HNO Kongress in Paris 1961 demonstriert werden Es wurde ein neuer physikalischer Effekt vorgetragen Analog dem Stromungsgesetz von Bernoulli lasst sich eine Schallverstarkung aus der Trichterform der Nische ableiten Sie durfte im wesentlichen auf einer Vergrosserung der Schallschnelle (Teilchengeschwindigkeit) beruhen

Dem Verfasser ist es ein freundlicher Gedanke mit der damaligen Veroffentlichung Heermann und andere ermutigt zu haben ihre um dieses Thema kreisenden Ideen weiterzuentwickeln und in die Tat umzusetzen

Unser bisheriges operatives Bemuhen bei allen Schalleitungsschwerhorigkeiten zielt darauf ab 2 Prinzipien zu verfolgen

1 grosstmogliche Wiederherstellung der Schalldrucktransformation
2 Schaffung einer optimalen Schalldruckdifferenz

Ich teile einen Fall von Totalplastik nach Verlust von Trommelfell Hammer Amboss und Steigbugel mit die zu einem ungewohnlichen Horgewinn fuhrte bei der die erwahnten Prinzipien keine ausreichende Erklarung geben Vielmehr liegt eine Horverbesserung vor deren physikalische Erklarung bisher noch nicht beschrieben wurde

Diese erstmalig am 25 9 1955 in Norderney mitgeteilte Plastik (veroffentlicht im HNO Wegweiser am 31 1 56 Heft 8) ist ein von der Natur angebotenes Experiment am Menschen Es zeigt ein annahernd konstant gebliebenes Horergebnis das ich nach fast sechsjahriger Dauer im Juli 1961 auf dem Internationalen HNO Arztekongress in Paris mitteilen konnte

Nach einem Vortrag gehalten in Paris auf dem Internationalen Ohrenärztekongress 2 – 7 1961
Herrn Dr Lennart [illegible] in Dankbarkeit gewidmet

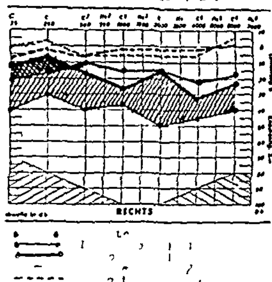


Abb. 1

Die 40jährige Patientin hatte ein ausgedehntes Cholesteatom. Vom Schallleitungsapparat existierte nur der Steigbügel. Bei Entfernung von Granulationen kam es zu einer ungewollten Luxation des Stapes. Deshalb extrahierte ich ihn und implantierte einen Hautlappen über dem ovalen Fenster. Derselbe Lappen bildete gleichzeitig eine kleine Pauke mit Tubenventilation. Das Schwellenaudiogramm für Luft- und Knochenleitung 4 Wochen sowie 6 Jahre nach der Operation zeigt den Hörgewinn (Bild 1). Die Knochenleitung hat sich etwas angehoben. Die Luftleitung zeigt einen Hörgewinn, der wesentlich über dem der Bogengangsfensterungsfälle liegt. Sie zeigt bis 500 Hz annähernd normale Werte; auch im mittleren Frequenzbereich liegt die Luftleitungskurve wider Erwarten hoch.

Dieser Hörerfolg gab Anlass zu folgenden Überlegungen:

1. Der umgebaute Lappen dürfte wohl keine elastischen Fasern enthalten. Doch wird an einem Membraneffekt kaum ein Zweifel sein. Trotzdem wird der Lappen nicht die gleichen elastischen Eigenschaften haben wie das Trommelfell, von dem wir wissen, dass es die günstigste Wellenwiderstandsanpassung um 800 Hz hat.

2. glaube ich, dass der Lappen eine andere Wellenwiderstandsanpassung haben wird als eine normal bewegliche Stapesfussplatte.

3. ist festzustellen, dass der Lappen nicht eine Invagination im Nischenbereich nach den mikroskopischen Kontrollen erfahren hat, sondern dass er den oberen Teil der Nische plan abdeckt. Es wird niemand bezweifeln



Abb 2

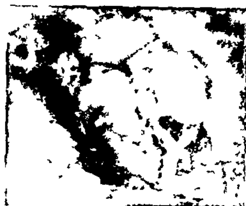


Abb 3

Abb 2 Status nach 6 Jahren

Abb 3 Punktierte Linie zeigt die vermutl obere Begrenzung des Transplantates über der Nische

dass die Nische im oberen Teil im allgemeinen wesentlich breiter ist als das ovale Fenster Die Abbildung 3 zeigt die denkbare Begrenzung des schwingenden Transplantates (anatomisches Präparat)

Naturlich sind Variationsmoglichkeiten bezuglich der Nischengrosse jedem Operateur bekannt Bei Sondierung des Transplantates besteht kein Zweifel dass die schwingende Flache uber dem Nischenbereich wesentlich grosser ist als erfahrungsgemass das ovale Fenster

Nach dieser Schilderung mussen wir also annehmen, dass der Perilymphraum sich um den Inhalt der mit dem Lappen abgedeckten trichterformigen Nische vergrossert hat d h die Nische ist zu einer mit Perilymphe angefullten Ausbuchtung des Vestibulums geworden

Bei der normalen Schalldrucktransformationseinrichtung des Mittelohres wird der Luftschall bekanntlich um etwa das Zwanzigfache verstarkt Diese erhebliche Schalldruckverstarkung erlaubt es eine geringfugige Interferenz erzeugende nachteilige Wirkung des Trommelfelldruckes auf die runde Fenstermembran zu vernachlassigen Bei dem geschilderten Fall jedoch zeigt die Herstellung einer kleinen Pauke einen maximalen Schallschutz

In unserm Fall fehlt der Schalldrucktransformator des Mittelohres vollstandig Dafur wird an der Nischenmembran aus Luftschall Wasserschall mit entsprechender zusatzlicher Beschleunigung

Nach dem allgemeinen Stromungsgesetz von Bernoulli hangt die Stromungsgeschwindigkeit vom Querschnitt ab Stromende Flussigkeiten haben bei kleinen Querschnitten grosse Geschwindigkeiten und geringen Druck In Gebieten grossen Querschnitts also weiten Stromlinienabstandes herrscht kleine Geschwindigkeit und grosser Druck Auf unsern Fall von 19[illegible] ubertragen heisst es dass der am Transplantat herrschende Druck relativ

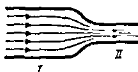


Abb. 4. Die Strömungsgeschwindigkeit hängt vom Querschnitt ab

gross ist, während in dem sehr viel engeren ovalen Fenster wesentlich grössere *Teilchen-Geschwindigkeit herrscht, dagegen der Druck geringer ist.* Dass heisst in unserm Falle liegt keine Drucktransformation vor, sondern die Verstärkereinrichtung besteht demnach in einer Verstärkung der Schallschnelle (Teilchengeschwindigkeit) (Bild 4).

Nehmen wir an, dass das Transplantat etwa 2 bis $2\frac{1}{2}$ mal so gross im Längs- und Querdurchmesser ist wie das ovale Fenster, so bedeutet das ein Flächenverhältnis von 4 bis 6 zu 1. Dementsprechend vergrössert sich die Schallschnelle auch vom Transplantat bis zum ovalen Fenster um das Vier- bis Sechsfache. Die Erhöhung der Schallstärke I in db durch die Vergrösserung der Schallschnelle v um den Faktor v_1/v_2 ergibt sich aus der Formel

$$I = 20 \log \frac{v_1}{v_2} \text{ db}$$

Daraus resultiert ein Hörgewinn von 12 bis 16 db.

Das zweite *Prinzip*, um das wir uns bei gehörverbessernden Operationen bemühen, besteht darin, eine optimale Druckdifferenz zu erzeugen. Das ist in dem vorliegenden Fall geschehen

1. durch den genannten Schallschutz, d. h. durch die Bildung einer *kleinen Pauke mit Tubenventilation, 2. durch die Bildung eines vergrösserten* Perilymphraumes. Dies bedeutet Zunahme der Trägheitskräfte und damit vergrösserte Schalldruckdifferenz. 3. verursacht der vergrösserte Perilymphraum vergrösserte Reibungskräfte, die ebenfalls eine Zunahme der Schalldruckdifferenz bedeuten. 4. wird möglicherweise durch den vergrösserten Perilymphraum der Phasenwinkel vergrössert und damit die Schalldruckdifferenz.

Als bei uns die Stapesmobilisation nach Rosen ihre ersten Erfolge zeitigte und die Bogengangsfensterung noch verbreitet war, habe ich diese Plastik ausgeführt. Ich habe seinerzeit mein operatives Vorgehen allen Kollegen empfohlen, denen einmal eine ungewollte Stapesluxation passieren sollte. Andrerseits w r *mir klar geworden, dass meine Beobachtung des sehr guten* Hörerfolges bei Fensterung des ovalen Fensters mit zusätzlicher Lappendeckung für alle gehörverbessernden Operationen von Bedeutung sein würde. Deshalb ist es mir jetzt noch ein freundlicher Gedanke, dass ich mit der Veröffentlichung dieses guten *Hörerfolges Heermann und andere ermutigt habe,* ihre um dieses Thema kreisenden Ideen weiterzuentwickeln und in die Tat umzusetzen.

PERCEPTIVE DEAFNESS IN CONNECTION WITH MUMPS

A Study of 298 Servicemen suffering from Mumps

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Two hundred and ninety eight servicemen being treated for epidemic parotitis at Military Hospital 2 in Turku were examined audiometrically and otologically. The purpose of the examination was to throw light upon the following questions:

(1) How often does perceptive deafness occur in connection with mumps;
(2) Does hearing improve later, and if so, how often, in the observed cases of deafness, and
(3) Do patients suffering from mumps induced meningitis exhibit affected hearing more frequently than patients suffering only from mumps?

It was seen that perceptive deafness in connection with mumps

(*a*) is not rare. Hearing loss occurred in 13 patients (4.4 ± 1.2 %).
(*b*) is usually reversible. Hearing became completely normal in six patients and almost normal in six patients, remaining unilaterally constantly and seriously affected in only one patient.
(*c*) has no correlation with mumps induced meningitis.

It was also seen that mumps induced deafness mostly appears in high tone range and that it may be bilateral.

It has been known for a long time that mumps is one of the many factors apt to cause sudden perceptive deafness. According to former opinions the typical deafness due to mumps is unilateral, of severe nature, irreversible and very rare. On the basis of more recent investigations mumps seems, however, capable of causing bilateral deafness, which is by no means always irreversible. It has also been possible to show that mumps, as well as certain other viral diseases, may bring about deafness much more frequently than had earlier been supposed.

Dishoeck & Bierman (1957) publish a material where 66 cases of deafness have been carefully studied regarding the possibility of viral infection being the probable cause of deafness. All the patients had sought medical care within three months of the appearance of their illness. The presence of viral infection could be seen in 21 patients. Mumps infection was present in fourteen cases, an infection of the influenza group in seven, and an infection of the poliomyelitis group in seven cases; two or even three different viral infections could be observed in some of the patients at the same time. In all the observed virus infection cases the authors considered the deafness to be due to the infection but they were also of the opinion that in a number of the

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Hamburg-Blankenese, Manteuffelstr.

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TABLE 1 *Audiometric findings*

Case no	Diagnosis	Date of tests	250	500	1000	2000	4000	6000	8000
918/58	Parot epid	5-26-58	0	-5	0	0	5	0	0
	c mening	6-13-58	20	15	20	30	30	30	30
		7-5-58	0	0	5	10	20	25	30
4/59	Parot epid	1 7-59	10	5	5	20	45	40	35
	c mening	1 27 59	5	0	0	0	25	5	0
6/59	Parot epid	1 7-59	0	5	-10	20	45	20	15
	c. mening	1-29-59	-5	5	-10	0	20	5	0
293/59	Parotitis epidemica	2 18-59	5	5	5	15	15	65	50
		3-18-59	5	5	5	15	15	25	20
		6-6-59	5	5	5	15	10	20	20
415/59	Parotitis epidemica	3 2-59	20	5	10	25	30	15	15
		3-14-59	5	0	5	15	15	10	5
		3 31-59	-5	-5	-5	5	10	0	-5
528/59	Parot epid c mening								
	Right ear	3-19-59	0	0	0	0	80	55	55
		3-23-59	0	0	-5	-5	0	0	-5
	Left ear	3 19-59	0	0	0	0	40	85	50
		3-23-59	0	0	0	0	35	0	0
		4-10-59	0	0	0	0	5	-5	-5
606/59	Parot epid	4 12-59	0	5	-10	-5	-5	5	-5
	c. orch	4 21 59	5	5	5	15	45	30	0
		7-5-60	-5	-5	-5	10	15	-5	-5
605/60	Parotitis epidemica	4 1-60	20	20	20	15	35	30	40
		4-25-60	0	5	0	0	5	15	0
828/60	Parotitis epidemica	5-9-60	10	5	15	20	[illegible]	50	45
		5 18 60	45	45	60	70	[illegible]	50	45
		8-16-61	55	60	75	80	95	0	60
846/60	Parotitis epidemica								
	Right ear	5-12-60	30	30	30	35	45	35	40
		5-30-60	0	15	10	20	45	35	40
		6 28-61	0	0	0	10	20	0	5
	Left ear	5-12-60	30	30	30	45	50	40	40
		5 30-60	0	10	0	20	35	10	0
		6 28-61	0	0	0	0	10	0	0
854/60	Parotitis epidemica	5-13-60	5	0	5	25	35	25	0
		[illegible]	0	0	5	15	5	0	0
		8 14-61	0	0	5	15	5	0	0
1083/60	Parotitis epidemica	12 1 60	15	0	0	5	25	40	35
		12 10-60	5	0	0	5	0	40	20
		12 20 60	0	5	5	5	0	10	15
[illegible]3/61	Parotitis epidemica								
	Right ear	1 11 61	10	5	10	35	40	0	5
		1 20-61	0	5	5	[illegible]	20	0	5
		3 13-61	0	-5	5	0	15	0	0
	Left ear	1 11 61	5	5	5	20	50	15	15
		1 20 61	0	5	0	15	5	5	0
		3 13 61	0	-5	0	5	0	0	0

Table 1 shows that

(1) Two patients (918/58 and 666/59) exhibited completely normal hearing when admitted to hospital. The former developed a slight perceptive deafness which was observable throughout the sound range and which improved gradually to normal for low tones, a slight defect remaining for high ones. During hospital treatment the latter patient developed fairly severe high tone loss, which disappeared by degrees.

(2) Slight perceptive deafness affecting the whole sound range was observed in two patients (605/60 and 810/60) when they were admitted to hospital. In the former case the defect improved to normal quite rapidly, in the latter case hearing improved more slowly and a slight defect in hearing was observed at 1000 cps in a follow-up examination carried out a year after the treatment.

(3) When taken to hospital nine patients exhibited moderate or severe deafness almost exclusively at the high tone range. In eight cases the defect disappeared either completely or almost completely within a few weeks. In one case (828/60) hearing continued to deteriorate and the condition developed into severe and constant deafness which covered the whole tone range.

(4) Among the patients suffering from defective hearing there were four cases (about 30 %) with mumps-induced meningitis. In all the cases the defects were quite slight and in one of them hearing rapidly returned to normal, slight defects remaining in the rest of the cases. In the whole material 83 patients (about 28 %) had mumps-induced meningitis. No correlation could be seen between hearing defects, on the one hand, and the clinical picture or the laboratory findings obtained for the patients suffering from meningitis, on the other. The number of the cells in the spinal fluid was 316–171/mm³ for such meningitic patients as exhibited hearing defects. Even greater numbers of cells were observed in several cases in connection with such meningitic patients as exhibited no hearing defects and the only patient in the material whose hearing remained constantly severely affected (828/60) was not suffering from meningitis at all.

(5) *In three cases slight deafness was observed in both ears; in every one of them the condition was quite symmetric.*

Comment

The investigation carried out has shown that perceptive deafness in connection with mumps in a material of patients at the age of 20

(*a*) are not very rare,
(*b*) are mostly reversible and affecting the high tone range, and
(*c*) have no correlation with mumps-induced meningitis.

On the basis of the present material it seems likely that deafness in connection with mumps is not very rare and that it is almost always reversible, hearing gradually becoming either normal or at least practically normal.

Hearing remained severely defective in only one patient (828/60) of the total material This one case does not permit even a rough estimate to be given regarding the frequency of such mumps induced hearing defects as are constant and of real hindrance to the patient particularly as one has to bear in mind that almost every person that comes into contact with patients suffering from mumps will get a mumps infection without manifest parotitis and mumps induced hearing defects may as well occur in them as shown by Dishoeck & Bierman (1957) and Saunders & Lippy (1959) A rough calculation made by the present authors shows that mumps causes annually some 25 30 cases of severe deafness of constant nature in Finland (about one case per 200 000 people) It is quite obvious that mumps as well as other viral conditions cause perceptive deafness considerably more frequently than is generally assumed for although most of the patients with severe hearing defects will seek medical treatment it is still likely that in a good many cases no viral examinations are undertaken when trying to find out the etiology of the deafness

In connection with a material that consists of servicemen one is easily led to suppose that high tone loss would be caused by firing practice Through the use of anamnestic data it has been tried to make the part played by this possibility as small as possible Thus for instance all the 13 patients whose deafness was supposed to be due to the mumps had not taken part in any firing practice within 10 days before the occurrence of their illness But nevertheless the possibility is still present However cases 666/59 and 828/60 entitle us to conclude that mumps induced hearing defects mostly appear in the high tone range In the former case hearing was normal when the patient was taken to hospital and the defect appeared only after that in the high tone range in the latter case the hearing defect was at first noticeable for high tones and only later it also spread to include the low tones

ZUSAMMENFASSUNG

298 Wehrpflichtige die wegen Mumps im Militarkrankenhaus in Turku behandelt wurden sind audiometrisch und otologisch untersucht worden Der Zweck der Untersuchung war folgende Fragen klarzustellen

(1) wie gross ist der Prozent der Mumps Patienten bei denen perzeptive Schwerhorigkeit auftritt

(2) kann sich das Gehor spater bessern falls ja wie oft in den Fallen wo diese Krankheit Schwerhorigkeit verursacht hat und

(3) tritt Schwerhorigkeit ofter auf bei solchen Mumps Patienten bei welchen als Nebensymptom Meningitis aufgetreten ist als bei solchen welche die Krankheit ohne dieses Symptom durchmachten?

Auf Basis dieses Materials ist festgestellt worden dass die perzeptive Schwerhorigkeit bei den Mumps Patienten

(a) nicht selten ist Eine Verschlechterung des Gehors wurde bei 13 Patienten festgestellt (4 4 2 5 %)

(*b*) meist reversibel ist. Bei sechs Patienten wurde das Gehör wieder völlig normal, und bei sechs anderen wurde es fast normal, sodass die Verschlechterung des Gehörs, in verhältnismässig schwerer Form nur bei einem Patienten bestehen blieb.

(*c*) keine deutlich erkennbare Wechselwirkung zwischen der Meningitis und dem Auftreten der Schwerhörigkeit besteht.

Die Schwerhörigkeit tritt am häufigsten auf dem Gebiete der hohen Laute auf, und kann auch doppelseitig sein.

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SINUS THROMBOSIS AND OTOGENE SEPSIS

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The course of the thrombophlebitis in sinus sigmoideus and the most frequent complications is briefly mentioned, followed by a survey of the treatment from the first successful operation, performed by Lane in 1888 until the combined operative and chemotherapeutical treatment of our time.

A report is then given of the results of an investigation into the frequency of thrombosis in sinus sigmoideus in the whole Danish population in the years 1956–60 inclusive. In this period there have been altogether only 12 cases, and of these patients three died, corresponding to approximately 0.01 ‰ of the total number of deaths in these years. (In German examinations covering the period 1900–1925 sinus thrombosis was primary cause of death in 0.3 per cent of the total post mortems, i.e. no less than 300 times more.) The number of cases during the present five year period corresponds approximately to the number of cases in Denmark in one year only 10 years *ago—quite an amazing decrease. Concerning treatment, operation* was performed in all cases, and in addition chemotherapeutic treatment was given in very large doses.

Sinus thrombosis, or rather thrombophlebitis in sinus sigmoideus caused by an ostitic process originating from a suppurating otitis media, was in earlier times a not uncommon complaint. Exact figures for its occurrence are not obtainable, but from German examinations of post mortem material covering the period 1900–1925 it appears that sinus thrombosis is a primary cause of death in 0.3 per cent of all post mortems. For the same period there is more material regarding the frequency of complications in connection with otitis media, and of these, sinus thrombosis is found in 0.[illegible] per cent of otitis cases. Compared with other otogene complications Heymann, Heine and others find that *sinus thrombosis is the most frequent, followed by* meningitis. Mygind reaches the opposite sequence. In all material 3rd and 4th places are taken by subdural and cerebral abscesses.

A few notes on the typical course and the most frequent complications.

Suspicion of otogene sinus thrombosis is aroused when the general health suffers during an otitis media. General infection may manifest itself in one of two different ways: the pyaemic, with widely fluctuating temperature and numerous infected foci caused by embolia, and the septic form, with a con

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stant high febrile temperature and a strongly marked toxic general condition the two forms however overlap to some extent Complications thrombophlebitis in sinus transversus sinus sagittalis superior in sinus cavernosus and sinus petrosus superior and inferior meningitis subdural abscess and cerebral abscess Cause of death enumerated according to frequency meningitis and cerebral abscess (2/3) septic general infection metastasis e g pyopneumothorax and septic endocarditis Unusual causes vagus paralysis sinus haemorrhage

The first observations of the aetiological connection between sinus jugularis thrombosis and inflammation of pars mastoidea and petrosa were made at the beginning of the 19th century In 1818 John Abercrombie reported post mortem findings and in 1826 Robert Hooper described pathologic anatomical findings The first greater and more systematical description is due to Lembert and dates from 1836 During the following years a more extensive knowledge of the disease was gradually gained but it was some years before operative treatment was risked In 1880 Zaufal developed and published an operative technique which included both the opening and emptying of sinus and the underbinding of the vena jugularis which was much used for a number of years In 1884 Zaufal himself performed the first operation which as such was a success the patient however died of pneumonia two weeks after the operation The first successful operation resulting in the complete recovery of the patient was performed by Lane in 1888 and was the beginning of an entirely new epoch in the history of the disease

The mortality rate of the untreated disease was practically 100 per cent but this soon dropped to approximately 50 per cent at the turn of the century after the introduction of the operative treatment Improved operational technique (Heine Operationen am Ohr 1913) further reduced the percentage so that in the twenties several larger German statistics estimate a mortality percentage of 30 35 and this is further reduced during the thirties to 20 25 per cent by operation without other treatment

The next milestone is of course the introduction of the chemotherapeutical and antibiotical treatment commencing in a small way with prontosil in 1932 sulfanilamid in 1935 and penicillin during and particularly after the Second World War This combined with operative treatment has produced very good results indeed especially in regard to the formerly much feared complications

In the Scandinavian symposium Penicillin in Severe Oto rhino laryngological Complications published in 1950 based on Nordic findings from 1948 (from 50 different wards and clinics) I P Vald Poulsen writes about chemotherapeutical treatment of tonsillogene and otogene thrombophlebitis and sepsis The material consisted of 33 cases of which 25 were of otogene origin Of these 10 were without complications 14 complicated by meningitis and one by cerebral abscess All patients were operated on 19 of them with opening of the sinus and in 10 of these underbinding of the vena jugularis interna was performed Exposure of sinus only to a greater or lesser extent

was performed on the remaining patients but in two of these cases the sinus had to be opened later Furthermore all patients were treated with penicillin the greatest dosage given being 1 2 million units per 24 hours, but two thirds of the patients received doses of between 100 000 and 800 000 units per 24 hours In addition all patients were given a sulfa preparation

The result of the treatment was that 22 patients recovered and three died Of these two cases were complicated by meningitis and the third by cerebral abscess Thus all uncomplicated cases recovered This corresponds to a mortality rate of 12 per cent of the total number of cases, 20 per cent of the cases with complications These results are in line with other statistics for the same period Koebbe and Potter *inter alia* who in 1944 reported 100 per cent recovery of the 14 patients treated with operation plus sulfathiazol penicillin In 1946 Hartmann reported a recovery percentage of approximately 90 after operation and sulfa treatment but without penicillin Several other sources show that complications in particular are on the decline

About 1950 it was still an open question whether an operation ought to be performed and especially when and how radically it was correct to proceed There seemed however to be agreement that underbinding of the vena jugularis was unnecessary and in fact contraindicated as chemotherapy appears to control septic metastasis Jugularis underbinding had been re garded with some scepticism in many quarters even before the penicillin era Various statistics showed already in the twenties a rather better percentage of recovery in non underbound cases Underbinding does not prevent transfer of infection to the blood stream and it involves several risks circulatory disorders in the cerebrum with consequent conditions dangerous to life further extension backwards of the thrombosis as well as lesions of the vagus accessorius and ansa hypoglossi Finally there is a certain risk of air embolism

The trend in Vald Poulsen s work (as in the whole symposium) is clear it is to be expected that penicillin and antibiotical treatment altogether—will be of great importance in the treatment of uncomplicated sinus thrombosis as well as and particularly of the complications Of course one should not be led to believe that penicillin is the absolute cure all The greatly im proved hygienic and nutritional standard of the population and the conse quent increased resistance the access to better and quicker medical assistance and the improved possibilities of receiving specialist treatment especially in the country have all proved of great importance

If one is to rely on the promising forecast of the symposium in 1950 sinus thrombosis should now have become a very rare complaint and in the few cases still occurring treatment should give good results In particular septic complications which in the past were found in from 25 to 50 per cent of all cases should have decreased very considerably

From the day to day work of the wards it is obvious that these diseases have become rare but how rare? Activated by a case admitted here in Nykobing F in December 1960 we found out that no statistics exist later than the above mentioned ones from 1950

TABLE 1. *Age and sex distribution*

Deaths are indicated by the sign (†)

	Under 15 years	15–29	30–39	40–49	50–59	60–70	Over 70 years
♀		1 (†)	2				1
♂	1	2 († †)	1 (†)	3	1		

In order to investigate whether these illnesses really *had become so rare* and in order to obtain useful statistics—if possible, figures for the whole country for the period 1956–60—questionnaires were sent to all otological wards and all otological consultants entitled to allow admissions to and give treatment at the respective infirmaries—altogether 43 questionnaires comprising 31 to wards and 12 to consultants.

All questionnaires were completed and the material obtained must therefore be regarded as most satisfactory, as it includes the whole population during the above 5-year period. In the period concerned there have been altogether 12 cases of certain sinus thrombosis (as well as three more cases in which the diagnosis does not appear to be quite certain and these are not taken into account in the following). The 12 cases are as shown in Table 1.

Of these 12 patients three died: one a woman of 20 years of age and two men of 25 and 38 years of age.

By comparing them with Vald. Poulsen's material from 1948–49 it will be noted that the number of cases, as expected, has dropped considerably. A direct comparison is difficult, as it is not shown how many of the 25 cases from 1948 are from Denmark and how many from Norway and Sweden. An indication of this may be found in the number of replies to the symposium as a whole, which from Denmark, Norway and Sweden were 189, 15 and 217 respectively. Used statistically, these figures give a number of 11 cases for the year under review for Denmark. This figure is far too low, as not all otological wards contributed to the research in 1948. By and large, therefore, the same number of cases occurred during 1948 as during the present five-year period—quite an amazing decrease within 10 years.

The mortality percentage, however, is greater than in 1948, being 25 per cent as against 12 per cent. The figures treated are, of course, very few—too few indeed for any conclusions to be drawn from them. But they are the only ones available and they do seem to indicate that more effective treatment, in particular chemotherapeutical treatment, arrests most cases at an early stage, thus leaving only the more serious cases with a consequent higher mortality.

The actual number of deaths, three in five years, corresponds to approximately 0.01 ‰ of the total number of deaths in this period. At the beginning

TABLE 3. *Complications*

Deaths are indicated by the sign (†)

Cerebral and cerebellaric abscesses	Epilepsy (?)	Facialis paresis	Tinnitus vertigo	Without complications
Abscessus cerebri (lob. temporal.) ♀ 20 (†)	♂ 7	♂ 10	♂ 14	♀ 30
		♂ 51		♀ 31
				♀ 77
				♂ 28
				♂ 13
Abscessus cerebelli				
♂ 25 (†)				
♂ 38 (†)				
♂ 51				

In 83 per cent of the cases under review it was found sufficient to perform resection and wide opening to the sinus, which was exposed to the extent of the infected part. In half of these cases craniotomy was furthermore performed due to epidural or cerebellaric abscesses. In only one case was it later necessary to open for the sinus, while in two cases this was done primarily. In one case jugularis underbinding was performed.

As regards the occurrence of sinus thrombosis in connection with acute and chronical otitis respectively, this is, as expected, far more frequent in connection with chronic cases. In only two cases (a boy of seven and a woman of 34 years of age) no earlier otitis was suspected. The remainder had had chronic discharge from the ears for a varying number of years right up to a period of 40 years. In one case nothing is known about possible *earlier otitis*.

Complications too are of interest (Table 3).

By far the most serious, the direct cause of death in all three fatal cases mentioned, is abscessus cerebri or cerebelli. In only one case has a patient suffering from this complaint been saved, and this was more in the nature of a miracle, since, to begin with, it was a case of multiple cerebellaric abscesses *which were treated neuro-surgically with temporary effect*. Later the condition of the patient deteriorated as a consequence of a large infected cerebellic haematom with duraprolapse through the cicatrice. The general condition of the patient was so poor that the neuro-surgeons had given up hope for him. He improved, however, because a heroic puncture of the lower lying haematom (it extended as far as toward pons) was performed by the otological surgeon. This patient, six months after the operation, still suffers from reduced strength in his right arm, poor diadochokinesis, defective speech and a certain mental deficiency. There is furthermore a post-operative right-handed facialis paresis, and the patient's right ear is totally deaf. The

patient had, however, suffered an earlier haemorrhagia cerebri, which partly accounts for the symptoms, at least in combination with the actual disease

Apart from this there have been few complications The boy of seven suffers from a possible post operative epilepsy as there has been the odd 'absence'' as well as slight focal convulsions of the right hand crus and femur The patient has recently been hospitalized for this and nothing abnormal was found with any degree of certainty, the EEG in particular was normal

As regards facialis paresis, one of these turned out to be caused by a small bone spica, which had pierced the facialis in foramen stylomastoideus and the paresis subsided when the bone was removed at a later operation The other case of paresis is the very severe one mentioned above

One patient suffered from dizziness and tinnitus for some considerable time but five cases had an entirely uncomplicated course and the patients recovered completely, apart from more or less reduced hearing of the operated ear

To recapitulate Sinus thrombosis has nowadays become an extremely rare disease At the same time, the few cases which do occur tend to be particularly severe, so that the mortality rate is rising The chances for recovery are, however, good as long as the correct treatment is applied in time It is therefore of importance that this complaint is borne in mind in the case of every otitis, the course of which deviates from the normal

ZUSAMMENFASSUNG

Der Verlauf des Thrombophlebitis in Sinus sigmoideus und die haufigsten Komplikationen sind kurz genannt Danach eine therapeutische Übersicht von der ersten gelungenen Operation (Lane 1888) bis zu der heutigen operativen und chemotherapeutischen Kombinationsbehandlung

Hierauf sind die Resultaten von einer Untersuchung über die Thrombose Haufigkeit in Sinus sigmoideus in der ganzen dänischen Bevölkerung in den Jahren 1956 60 inklusiv mitgeteilt Man hat im allen nur 12 Fälle gefunden von welchen nur 3 Patienten gestorben sind entsprechend etwa 0 01 ‰ von den Todesanzeigen in diesen Jahren (In deutschen Untersuchungen von 1900 1925 war Sinus thrombose Todesursache in 0 3 % von den Todesanzeigen, d h 300mal häufiger) Die Anzahl der Fälle wahrend der funfjährigen Periode entspricht so etwa der Anzahl der Fälle in einem Jahre in Dänemark nur vor 10 Jahren Die Behandlung war in allen Fällen Operation mit Chemotherapie in grossen Dosen

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CHANGES IN BONE CONDUCTION AFTER OVAL WINDOW FENESTRATION

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Data are reported on 116 cases of oval window fenestration in which the pre- and post-operative bone conduction thresholds were compared. It appeared that in this series there was significant improvement post-operatively at all frequencies, the changes being larger at 1000 and 2000 cps (5.5 to 5.7 db) than at 250, 500 and 4000 cps (2.2 to 2.8 db). The incidence of improvement was largest in C cases and diminished with better pre-operative bone conduction figures. Results comparing the bone conduction thresholds with the tested ear open or closed showed that the latter technique introduces slight error in the post-operative thresholds, some improvement occurring via air conduction, which is now nearly normal. The value of speech tests in pre-operative selection is emphasized.

It is well known that lowered bone conduction thresholds do not reflect an impairment of the sensorineural mechanism alone, but can also be found in certain cases of conduction deafness. This fact was recognized even in the pre-audiometric era by Rejto and by Krainz (1926) on the basis of tuning fork tests. Krainz clearly stated that lowered bone conduction values occur in otosclerosis with bony overgrowth in the round window region, in cases with tubal occlusion and negative middle ear pressure as well as in serous otitis media.

During the audiometric era the hearing tests have become much less laborious. As late as 1948, however, Juers reported on bone conduction changes in 28 cases of otosclerosis, and then followed two reports of Woods (1948, 1950). These findings in otosclerosis were later corroborated, though with some differences in the magnitude of the change, by several other investigators.

Mechanical lowering of bone conduction thresholds in cases of otitis media or of serous otitis was demonstrated by Palva & Ojala (1955). Palva & Pulkkinen (1960) described a similar artificial lowering in bone conduction thresholds in chronic otitis media with tympanic pathology limiting the movements of the windows. In these latter cases the authors felt that in evaluating operability the bone conduction values alone should not be relied upon and recommended subsidiary speech tests for proper evaluation of pre-operative cochlear function.

The mechanism causing artificial bone conduction depression in otosclerosis and in various inflammatory conditions or their sequelae is obviously not identical. In the latter group there is probably a general damping of the movements of the windows, whereas in otosclerosis the round window movements should, as a rule, be free and those of the oval window hindered. One would therefore expect the bone conduction changes in uncomplicated otosclerosis to be of a minor degree as compared with bony fixation of both windows, in which a severe bone conduction impairment should be present.

The increase in stiffness caused by stapes fixation results in a low tone loss in air conduction tests. In bone conduction the changes should mainly be due to the loss of inertia forces, the skull and the ossicles moving now more or less as a fixed block. Compression bone conduction, on the other hand, should not show much change, as the round window allows an effective yielding. One would thus expect the main changes in bone conduction to appear at frequencies below 1000 cps. The inertia and compression mechanisms overlap, however, and both have some function over the whole auditory area.

REVIEW OF EARLIER STUDIES OF BONE CONDUCTION IN OTOSCLEROSIS

The results from the period of horizontal semicircular canal fenestration are summarized in Table 1. It must be emphasized that the table includes only those cases in which the post-operative examination took place after a sufficient healing period to allow normal conditions in the middle ear. Juers found the greatest improvement at 2000 cps, as much as 13 db; at 250 there was no change and at 500 and 1000 the average change was less than 5 db. Woods did not report the changes at individual frequencies but gave an average figure of 11.4 db for the three middle frequencies. Y. Meurman had improvement in bone conduction from 10 to 40 db in 54 cases in a series of 105 fenestrations. The subsequent authors have obtained figures varying somewhat from those given above and from each other, but the general impression is that the major changes occur at 1000 and 2000 cps, both the low and the high end presenting little if any improvement.

Similar studies were conducted during the mobilization period and the results of three authors are presented in the lower half of Table 1. Rosen & Bergman *concluded on the basis of their early series in 1955 that in* "A" cases there will be no improvement; as a matter of fact the postoperative values were depressed beyond the preoperative figures. In "B" and "C" cases the changes were clearly greater, increasing with increased depression of the pre-operative bone conduction thresholds. In a later report (1960) the values for "A" and "B" cases in a series of 155 mobilizations did not show much change from the pre-operative figures and the authors concluded that the changes were too small to influence meaningfully the selection of cases for mobilization operation.

TABLE 1 *Bone conduction changes after classical fenestration and stapes mobilization*

Author and year	Types of cases	No of cases	Frequency 250	500	1000	2000	4000
		FENESTRATION					
Juers (1948)	Mixed	28	0 8	3	4 2	13	—
Woods (1950)	B & C	39	—	Average 11 4 db			—
Meurman (1950)	Mixed	54		From 10 to 40 db			
Nilsson (1952)	A	10	2 5	6	7	14	
McConnell & Carhart (1952)	Mixed	58	1 2	1 4	6 5	8 5	4 2
Henner (1954)	Mixed	62	—	2 5	8 7	8 2	7 5
Miller *et al* (1961)	Mixed	68	1 4	3 3	7 6	6 8	0 3
		MOBILIZATION					
Rosen & Bergman (1955)	A	13	−0 6	−3 1	−1 3	−8 1	−9 2
	B	31	4 8	6 8	6 5	3 2	4 8
	C	13	7 3	12 1	13 3	5 4	−3
Rosen *et al* (1960)	A	55	−0 8	−0 7	−0 1	0 7	0 5
	B	100	2 0	0 7	1 8	3 7	3 5
	A+B	155	1 0	0 2	1 3	2 1	2 1
Miller *et al* (1961)	Mixed	32	1 3	0	4 5	3 1	3 6

Miller *et al*, recently reported results on 68 cases following fenestration surgery and on 32 cases of stapes mobilization The latter series showed clearly less change than the former the average improvement being maximal at 1000 cps (4 5 db) followed by 4000 cps (3 6 db) and 2000 cps (3 1 db) At low frequencies there was no appreciable change compared with the preoperative thresholds

MATERIAL AND METHODS

The total material subjected to individual analysis comprises 116 patients all of whom were operated on by oval window fenestration technique with fascial graft Either the original stapes or a polyethylene prosthesis was placed between the oval window and the lenticular process of the incus If possible the whole stapes footplate was removed (Meurman & Palva 1962)

All patients were tested pre operatively by the usual routine audiometry including speech tests Speech discrimination tests were considered indispensable because even with poor air and better bone conduction the chances for a successful result were reasonably good in the presence of good speech scores Good speech discrimination was considered essential to safeguard against false results which in bilateral conduction deafness may sometimes

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TABLE 2 *Bone conduction improvement at various frequencies*

Improvement db	Frequency, cps				
	250	500	1000	2000	4000
−5	37	40	25	23	45
0	25	31	22	30	26
5	31	19	26	19	19
10	16	8	19	17	13
15	4	14	14	12	8
20	3	4	5	11	3
25	—	—	4	3	2
35	—	—	1	1	—
Total	116	116	116	116	116

Table 3 shows the frequency at which the grouped averages differ from the pre-operative figures For the three middle frequencies 75 cases (65 per cent) show no significant change while an improvement exceeding 10 db is observed in 22 cases (19 per cent) For the five grouped frequencies these figures are somewhat lower 62 and 11 per cent respectively

Table 4 finally shows the postoperative average improvement at individual frequencies including their standard deviations and standard errors The maximum average improvement is seen to occur at 1000 and 2000 cps at 250 500 and 4000 cps the values are clearly smaller Standard deviations are on the whole quite large indicating considerable spread of the results (cf Table 2)

The standard error of the means shows that, at the various frequencies the average post operative improvements are from three to seven times larger than the standard error Comparison of the means for the three frequencies (250 500 and 4000 cps) and the means for the two middle frequencies (1000 and 2000 cps) discloses that the standard error is of the order of 1 0 to 1 1 and thus the differences between the means for these two separate groups are from 2 9 to 3 3 times the standard error

Breakdown of the data into A B and C cases gives somewhat more information of the incidence of the improvement in various types of oto sclerosis The division was here made only on the basis of the bone conduc

TABLE 3 *Improvement in bone conduction thresholds for grouped frequencies*

Average	Amount of improvement db					
	5 to 5	5 1 10	10 1 15	15 1 20	Over 20	Total
Three frequencies	75	19	13	8	1	116
Five frequencies	72	27	6	[illegible]	[illegible]	112

TABLE 4 *Average bone conduction improvement at various frequencies*

Frequency cps	Average improvement	S D	S E
250	+2 2	6 0	0 6
500	+2 3	7 1	0 7
1000	+[illegible] 5	9 0	0 8
2000	+5 7	9 2	0 9
1000	+2 8	7 7	0 7

tion values for the three middle frequencies an "A" case thus has no value at these frequencies below 10 db a "B" case not under 20 db the "C" group including all remaining cases The results of this subdivision are given in Table 5 the three middle frequencies being dealt with as average grouped figures

It is evident that in each group the majority of cases showed no appreciable post operative change the values lying within ±5 db of the pre operative figure Average improvements exceeding 5 and 10 db occur in all groups but *their number increases with the degree of pre operative bone loss* Values exceeding 5 db occur in group "A" in 24 per cent of all cases The corresponding figures for "B" and "C" cases are 31 and 38 per cent

The correlation between results with the tested ear open or closed was only calculated for the three grouped middle frequencies Whereas in the routine test (ear canal open) there were 41 instances in which the post operative improvement was 5 db or more (cf Table 3) their number with the ear canal covered was 69 Expressed as percentages these figures are 35 ±4 7 db and 47 +4 6 db The standard error is 6 6 The difference of 12 db between the means is therefore suggestive but not fully significant

DISCUSSION

The data reported above seem to prove clearly that there is a significant improvement in the bone conduction thresholds following oval window

TABLE 5 *Improvement in various subgroups for three middle frequencies*

Classification	Magnitude of change db			
	±5	5 1 10 0	Over 10	Total
A cases	13	1	3	17
B cases	29	11	4	44
C cases	34	6	15	55
Total	76	18	22	116

fenestration This improvement is smallest at 250 500 and 4000 cps but even here the standard error of the means is three to four times the observed difference from the preoperative figures At 1000 and 2000 cps the observed differences are six to seven times the standard error it is not possible that any of the values had arisen by change

It is also evident that the greatest improvement occurs at 1000 and 2000 cps both the lower and higher frequencies showing less change The standard error of the means between these two groups of frequencies is of the order of 1 0 and thus the differences observed are about three times the standard error Here too it is unlikely that the differences had arisen by chance

These results seem to agree with the majority of earlier studies based on classical fenestration or stapes mobilization in the qualitative assessment of improvement at various frequencies The magnitude of the change has no exact parallel in either the horizontal semicircular canal fenestration or stapes mobilization groups but rather represents an intermediate position between the extremes reported at a given frequency Obviously all series are affected by the type of cases included the greater the number of B and C cases with more marked pre operative bone conduction depression the larger will be the average post operative improvement

From their later series (1960) Rosen & Bergman concluded that the bone conduction changes are too slight to influence meaningfully the selection of cases We agree with this statement only in considering that all cases with some cochlear reserve are suitable condidates for oval window fenestration provided their speech discrimination is good and that the expected improve ment would significantly improve the patient s social adequacy However we should like to stress that in some cases in accordance with the earlier report of Rosen & Bergman (1955) there is a considerable post operative improvement in bone conduction (and correspondingly in air conduction) which should be remembered in pre operative selection

The data obtained also present enough evidence in favour of the rule that the tested ear should be open in bone conduction testing It is true that the differences between the two series were not large and it obviously is a different matter if the ear canal is tightly closed with a finger (or plug) or if only a rather loose receiver is on the auricle

With the ear canal open the extraneous noise in the testing room may cause some masking in the low tone thresholds but if not much importance is attached to results at 125 and at 250 cps the higher frequencies should show reliable findings

Finally it should be emphasized once more as stated earlier by Palva & Pulkkinen (1960) and by Palva & Palva (1962) that speech discrimination tests are an invaluable asset in evaluation of the cochlear function in mixed deafness If speech scores are good even a large pre operative bone con duction loss in otosclerosis is no contra indication to oval window fenestra tion and does not limit the improvement to what is expected on the basis of the pre operative bone conduction level alone

ZUSAMMENFASSUNG

Bei 116 Fällen, an denen eine Fenestration des ovalen Fensters ausgeführt wurde, verglich man die pre- und postoperativen Knochenleitungsschwellen Bei dieser Untersuchung konnte eine bedeutende postoperative Verbesserung bei allen Frequenzen festgestellt werden, und dass die Verschiebungen bei 1000 und 2000 Hertz (5,5 bis 5,7 db) grosser als bei 250, 500 und 1000 Hertz (2,2 bis 2,8 db) waren Am auffälligsten war die Verbesserung in "C"-Fallen und nahm mit besseren preoperativen Knochenleitungswerten ab Ein Vergleich der Ergebnisse, die man bei geöffnetem und geschlossenem Gehörgang erhielt, zeigte, dass das letztere Verfahren zu gute Werte der postoperativen Schwellen liefert, eine zusatzliche Verbesserung tritt über die Luftleitung ein, die jetzt fast normal ist. Der Wert von Sprachtests bei der preoperativen Auswahl wird betont

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ELECTRONEUROGRAPHIC EVIDENCE OF MUSCLE SPINDLES AND OTHER SENSORY ENDINGS IN THE INTRINSIC LARYNGEAL MUSCLES OF THE CAT

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Electroneurographic investigations carried out on afferent fibres of the recurrent nerve associated with laryngeal slowly adapting receptors are described in this paper The modifications of the afferent discharges of the recurrent nerve due to passive stretch and electrical stimulation applied to the intrinsic laryngeal muscles are highly suggestive of muscle spindle activity Other proprioceptors showed the functional characteristic of the proprioceptors in series with the fibres of a muscle There is now functional evidence that the intrinsic laryngeal muscles are provided with a stretch receptor mechanism This should account for the existence of a myotatic control of these muscles

INTRODUCTION

Muscle spindles appear to subserve the control of the activity of more numerous muscles than had first been suggested and it is a recent acquisition that non weight bearing muscles such as the extrinsic muscles of the eye (Cooper Daniel & Whitteridge 1955 Whitteridge 1960) are provided with such control

The regulation of the movements of the vocal cords is still a matter of hypothesis (Rudolph 1956) a possible assumption is that a muscle spindle mechanism might play a role also in the control of the activity of the intrinsic laryngeal muscles

Muscle spindles have been seen histologically in the intrinsic muscles of the larynx of man and animals (Brocklehurst & Edgeworth 1940 Goerttler 1950 Paulsen 1958 a b Konig & von Leden 1961 Lucas Keene 1961 Rudolph 1961) though no experimental evidence of spindle activity from these muscles has so far been presented The recurrent nerve of the cat has been shown to contain proprioceptor fibres which end in the intrinsic laryngeal muscles (Bianconi & Molinari 1960 1962)

The possibility has now been investigated that some of these fibres are associated with such receptors as muscle spindles

METHOD

The experiments have been carried out on cats anaesthetized with Nembutal (60 mg/kg) given intraperitoneally. A tracheal cannula was inserted. Both the recurrent nerves were isolated along the sides of the trachea and cut as caudal as possible. Few fibre and single fibre preparations were made from the peripheral nervous end. Such preparations were laid on saline wet electrodes in connection with a resistance capacity amplifier and checked for activity by means of a loudspeaker. Records were taken with a Cossor 1049 Mk IIIA oscillograph.

The larynx was isolated from the surrounding tissues, so that only the connections of the larynx with the superior thyroid arteries and the recurrent nerves were left. The larynx was immobilized by fixing the antero-cranial edge of the thyroid cartilage. Sometimes it was more convenient to expose each vocal cord by cutting the thyroid cartilage along the midline; in this case each half of the cartilage was fixed.

In order to produce passive abduction or adduction of the vocal cords a thread was passed through the superior edge of each arytenoid cartilage and fastened to it. A light weight (3–5 g) was applied to the other end of the thread. By means of a system of pulleys and a change of the position of the threads, the direction of traction could be modified so that abduction or adduction was obtained when required.

Slowly adapting discharges were thus readily obtained from several few fibre preparations of the recurrent nerve. They were tested for muscle spindle activity from the thyro-arytenoid and the posterior crico-arytenoid muscles.

Spindles of one of these muscles were identified as those nerve endings whose stretch discharge was interrupted during the contraction of the same muscle (Granit 1955). This was elicited by direct stimulation with single or repetitive shocks from a Tektronix stimulator. Duration of the square waves was 1–3 msec and the strength high enough to cause a visible contraction.

RESULTS

Fig. 1 shows a typical example of the electrical activity recorded from spindle fibres of the right thyro-arytenoid muscle. The slowly adapting discharge elicited by the passive traction of the vocal cord was interrupted during the contraction of the thyro-arytenoid muscle caused by the electrical stimulation (Fig. 1*a*) and was increased by the contraction of the crico-arytenoid muscle, whose activity extends the vocal muscle (Fig. 1*b*).

Muscle spindle discharges were also detected from the right posterior crico-arytenoid muscle (Fig. 2). Such spindles were activated by the passive adduction of the vocal cord (Fig. 2*a*, *b*) and by the contraction of the thyro-arytenoid muscle. The discharge of these spindles was interrupted during the contraction of the same posterior crico-arytenoid muscle elicited by single (Fig. 2*c*) or repetitive shocks (Fig. 2*d*).

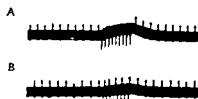


Fig. 1. Muscle spindle activity from a nerve ending of the thyro-arytenoid muscle. Cat. Nembutal anaesthesia. Single fibre of the right laryngeal recurrent nerve. Steady impulse activity elicited by passive stretch of the homolateral vocal cord. The nerve ending discharge is interrupted during the contraction of the homonimous muscle (*A*) and is slightly increased during the contraction of the heteronimous muscle (*B*). Downward deflections, in both records, are artefacts showing electrical stimuli (20/sec, 3V, 3 msec) applied directly to the pertinent muscle. (In these and following records, the slow upward shift of the baseline occurring simultaneously with the downward deflections is also an electrical stimulation artefact, not a biological potential.)



Fig. 2. Muscle spindle activity from a nerve ending of the posterior crico-arytenoid muscle. Cat. Nembutal anaesthesia. Single-fibre preparation of the right laryngeal recurrent nerve. *A* and *B* are from same recording; *B* 2 sec after *A*. First arrow: passive adduction of the right vocal cord elicits a steady activity. Second arrow: the activity ceases on releasing. *C* and *D*: direct electrical stimulation of the right crico-arytenoid muscle. *C*: single shock (3V, 1 msec). *D*: repetitive shocks (20/sec, 3V, 1 msec). During the contraction of the muscle the nerve ending discharge is interrupted.

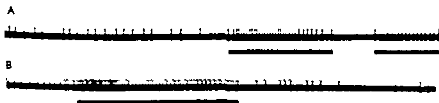


Fig. 3. Activity from a stretch receptor of the thyro-arytenoid muscle during stretch and during local probing on the site of its localization. Cat. Nembutal anaesthesia. Single proprioreceptor fibre of the laryngeal recurrent nerve. *A*: at signals antero-posterior stretch of the homolateral vocal cord. *B*: at signal mechanical stimulation of the site of the receptor.

Direct pressure with a probe on the appropriate area of the intrinsic muscles of the larynx made the nerve endings discharge as long as the pressure was applied. When the ending was already firing, probing increased the discharge frequency; on releasing, the discharge had a sudden temporary

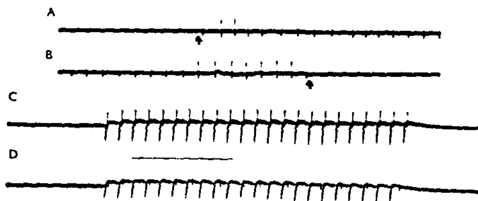


FIG 4 Another type of proprioreceptor of the intrinsic laryngeal muscles An 'in series' nerve ending of the thyro-arytenoid muscle The ending is active both during the contraction of the homonimous and heteronimous muscles Cat Nembutal anaesthesia Single fibre preparation of the right laryngeal recurrent nerve A and B are continuous records Between arrows antero-posterior traction of the right vocal cord C direct electrical stimulation of the right thyro arytenoid muscle (10 sec, 3V, 1 msec) D direct electrical stimulation of the right crico-arytenoid muscle In C and D, impulses, upwards, stimulation artefacts, downwards

arrest The same probing on other areas of the same muscle did not affect the nerve ending under examination, new nerve endings instead were caused to fire This made it possible to identify the localization of several spindles in the muscle body In the case of Fig 3, the ending was located in a precise point a few millimeters caudal to the edge of the vocal cord about one third the length of the cord from its anterior insertion

In our experiments, discharges were more frequently originated from this site of the thyro arytenoid muscles, as regards the posterior crico arytenoid muscles, the endings were more frequently found in the extremity of the muscles nearer to the arytenoid cartilage

Other nerve endings of the thyro arytenoid muscle and posterior crico arytenoid muscle showed a different pattern of activity, this is illustrated in Figs 4 and 5 respectively

The thyro arytenoid receptors were firing steadily during a stretch of the vocal cord (Fig 4a b) however the stretch needed to be more intense than for the previously described nerve endings Furthermore, in contrast with the spindles, these receptors were made to fire also by the contraction of the thyro arytenoid muscle itself (Fig 4c) Obviously the contraction of its antagonistic, the posterior crico arytenoid muscle, was also effective in producing a discharge of these receptors (Fig 4d) in this case electrical stimuli of the same strength used for the contraction of the thyro arytenoid muscle were not always followed by a discharge of the nervous endings (Fig 4d), the distance between a stimulus and the following spike was variable and greater than with the contraction of the thyro arytenoid muscle (Fig 4c and 4d)

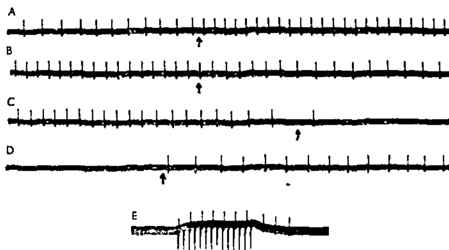


Fig. 5. Nerve ending in series of the posterior crico-arytenoid muscle. The ending is activated both by the traction and the contraction of the same muscle. Cat. Nembutal anaesthesia. Single fibre preparation of the right laryngeal recurrent nerve. *A* and *B* are continuous records. Between arrows passive abduction of the right vocal cord. *C* and *D* are continuous records. Between arrows passive abduction of the right vocal cord. *E* direct electrical stimulation of the right posterior crico-arytenoid muscle previously abducted.

Receptors which showed a similar pattern of activity were found also in the posterior crico-arytenoid muscle. In the case illustrated in Fig. 5 the spontaneous discharge of the receptor was increased in frequency by a strong adduction (Fig. 5*a*, *b*) and interrupted by the abduction of the vocal cord (Fig. 5*c*, *d*). The electrical stimulation of the posterior crico-arytenoid muscle elicited a firing of the receptor which had been silenced by a previous abduction of the vocal cord (Fig. 5*e*).

DISCUSSION

Some of the proprioceptor fibres detected in the recurrent nerve (Bianconi & Molinari 1960, 1962) showed discharge patterns highly suggestive of muscle spindle activity. Claims of indirect evidence of laryngeal muscle spindles have been presented by other authors (Campbell & Murtagh 1956, Esslen & Schlosshauer 1959). In the present paper direct functional evidence is given of muscle spindle activity originating from endings localized in the intrinsic laryngeal muscles, notably the m. thyro-arytenoideus (musculus vocalis).

The presence of muscle spindles in the intrinsic muscles of the larynx lacked histological evidence for a long time and it was also denied on the basis of the fact that the recurrent nerve appears as an unimodal nerve (Murray 1957). Only recently Lucas Keene (1961), König & von Leden (1961) reported these endings to be numerous in all the intrinsic la-

ryngeal muscles of man Rudolph (1961) however in a recent study still on man has spoken of them as not bearing typical histological features There is no information about the spindles in the intrinsic laryngeal musculature of the cat Whatever the histological features may be however the eng results presented in this paper are typical of what is considered muscle spindle activity that is the activity of nerve endings in parallel with the muscular fibres

Electroneurographic evidence for other proprioceptors than those in parallel has also been detected from the intrinsic laryngeal muscles These receptors showed the functional characteristics of the proprioceptors in series with the fibres of a muscle It is interesting to note in this context that histological observations of various types of sensory endings in the intrinsic muscles of the larynx have been reported by several authors (Sunder Plassman 1933 a b Mundnich 1937 1956 Lucas Keene 1961)

There is now functional evidence that the intrinsic laryngeal muscles are provided with a stretch receptor mechanism This should account for the existence of a myotatic control of these muscles It may offer a base for interpreting the postural activity described by Faaborg Andersen (1957) and also for the view that a myotatic control should integrate the respiratory and phonatory innervation of the agonistic antagonistic organization of the musculature acting on the vocal cords

ZUSAMMENFASSUNG

Man beschreibt in diesem Aufsatz durchgeführte elektroneurographische Untersuchungen an Afferenzfasern des Rekurrenznervs in Verbindung mit laryngealen sich langsam anpassenden Rezeptoren Die Veränderungen der Afferenzentladungen des Rekurrenznervs welche Folgen von passiver Spannung und elektrischer Reizung der inneren laryngealen Muskeln sind deuten stark auf Muskel Spindel Aktivität Andere Propriozeptoren zeigten die funktionelle Charakteristik der Propriozeptoren als in Serie mit den Fasern eines Muskels Es liegt jetzt ein funktioneller Beweis dafür vor daß die inneren laryngealen Muskeln mit einem Spannungs-Rezeptor Mechanismus versehen sind Dies dürfte das Vorhandensein einer myotatischen Kontrolle dieser Muskeln erklären

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CYTOPLASMIC BASOPHILIA IN THE SPIRAL GANGLION OF THE GUINEA PIG IMMEDIATELY FOLLOWING ACOUSTIC STRESS

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Guinea pigs were exposed to strong stimulation by white noise for 30 minutes to six hours. On examining the spiral ganglion immediately after terminating the acoustic stress, a significant reduction in the cytoplasmic basophilia was found on staining with gallocyanin chrome alum by Einarson's method at pH 1.64. No proportionality was found between the duration of the acoustic stress and the degree of cytoplasmic basophilia.

The research procedures developed during the last few decades for the qualitative and quantitative study of the metabolism of cells and tissues have also been applied with success to the study of the inner ear. Formerly, the reaction of the organ of hearing to a specific stimulus—sound in physiological and non-physiological doses—could only be studied by histomorphological methods, which include fixation and decalcification. However, modern techniques of microdissection (Neubert 1952, Beck 1956) have now made it possible to reveal the metabolic processes taking place in the labyrinth by means of the methods of histochemistry (Vosteen 1961).

The spiral ganglion is difficult of access for detailed cytological studies, lying as it does in a helical, thin-walled bony cavity. The ganglion cells of Corti are rather small, bipolar cells, uniform in size and structure. They are slightly larger, however, towards the base of the cochlea (Hammer 1956). Within the cell, the Nissl substance is fairly uniformly scattered throughout the cell in small and slightly larger granules, the latter found most often peripherally. On Einarson's classification, these cells seem to belong to the type of archyochrome nerve cells. Their specific stimulus is familiar and easily adjusted for dosage, and presumably they remain unaffected to a considerable degree by other noxia which may arise experimentally, in particular the anaesthetic employed. This cell type must be considered as belonging to the more primitive and embryonic-like among ganglion cells (Hydén 1943).

Many authors have described changes in the spiral ganglion following exposure to noise in physiological or traumatizing doses. These changes have normally been evaluated on morphological criteria and following traditional histological techniques, including fixation and prolonged de-

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calcification. It is only in recent years that histochemistry has been used to study the cell changes resulting from functional activity. Hamberger & Hydén (1945) using a combination of microdissection and slight decalcification have carried out fundamental studies on the RNA and protein content of these cells after stress, making the determinations by ultraviolet spectrophotometry. Hammer (1956) was able later to supplement these studies by means of radiospectrometry of fresh tissue cut in a cryostat, so that variations in the content of dry matter in the cells could be determined with great precision after the animal had sustained acoustic trauma. Chlodvig Beck (1956) has removed clumps of ganglion cells from fresh preparations by means of microdissection and carried out histomorphological studies on these not decalcified preparations.

The ganglion cell is outstanding for its very high metabolism, its relatively high content of RNA, which determines its pronounced basophilia, and its specific irritability. Possessing these characteristics it is particularly suited to an examination of the relationship between function and RNA content. As it is always found surrounded by other cells, biochemical analysis of the total tissue is unable to provide precise information on the RNA content of the individual cell type. Other methods are necessary therefore, including microphotometric determination of the cytoplasmic basophilia. These methods are based on stains which are specific for RNA (+DNA) and which are progressive, i.e. do not require differentiation. Such criteria are met by staining with Einarson's gallocyanin chrome alum (Einarson 1932). This is generally progressive, as it probably depends on a stoichiometric chemical relation between ions of a stain lake and phosphate in RNA, so that over staining cannot occur within a reasonable length of time (Pakkenberg 1958). Staining is specific for RNA at pH 0.7–1.84; at higher pH values there is an increasing co-staining of protein.

The aim of the present study was to examine changes in the cytoplasmic basophilia of the Corti ganglion cells immediately after withdrawal of a strong acoustic stress of varying duration.

MATERIAL AND METHOD

Seventeen guinea pigs were used, eight of them as control animals. Their weight varied from 300 to 400 g. Prior to the experiments the animals lived in quiet laboratory surroundings but not in a *camera silenta*. They were well nourished on a carotin-rich diet (Ruedi 1954) *ad libitum*. Their auditory-vestibular function was examined with the aid of Preyer's reflex and by testing postural reflexes.

The acoustic stress applied was white noise, for which purpose the masking noise from an M. P. Pedersen Audiometer (Type B 220, GE no. 9) was used, amplified to a total output of 127 db. The frequency analysis of the noise measured in db above $2 \cdot 10^{-4}$ µbar ⅓ octave gives the following character-

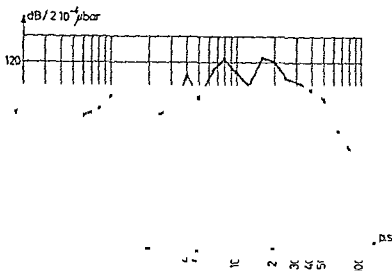


Fig. 1. Frequency analysis of the "white noise".

istic for the given sound effect measured at a distance of 50 cm from the aperture of the acoustic source (Fig. 1).

The animals were placed in a funnel shaped wooden box of the following dimensions: base 55 × 55 cm, distance from animal to acoustic source 50 cm. The bottom of the box consisted of a metal net resting on wooden strips. The animals were under urethane anaesthesia which was so deep that Preyer's reflex was abolished. The animals were exposed to the noise for a period of 30 minutes to six hours followed immediately by intravital fixation with 95% alcohol after perfusing the vascular system for ½ minute with physiological salt solution at body temperature at a perfusion pressure of 65 cm of water. After perfusing for one minute with alcohol, which as experience shows runs slowly through the vascular system, the animals were decapitated as rapidly as possible, the bulla was opened, then the cochlea apically, the stapes luxated and the whole immersed in 95% ice cold alcohol. The duration of the fixation procedure was at most 2 to 3 minutes. After 24 hours the modiolus with the ductus cochlearis *in situ* were prepared under alcohol with the aid of a Zeiss operation microscope. The preparation obtained was fixed for a further 24 hours in ice cold 95% alcohol, after which it was taken through to paraffin and the sections cut 10 µ thick in the long axis of the modiolus. The sections were then stained by Einarson's method with gallocyanin chrome alum at pH 1.64 for 48 hours at 18°C. They were then mounted in DPX. The thickness of the section was measured by focusing on the upper and lower surface, the mean value being very nearly 10 µ. The extinction was determined on the section by means of a microspectrophotometer (magnification × 3000). Interference filter lambda nanometer 580 was used. Measurements were made on 25 cells in each section at two points in the cytoplasm of each cell. The measuring field was

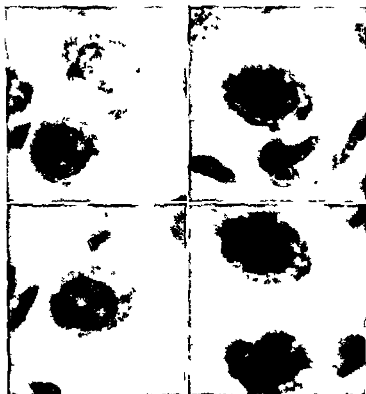


Fig. 2. Selected nerve cells from the spiral ganglion in normal guinea pigs. Gallocyanin.

1.32 μ in diameter. The measurements were made consecutively on all cells with the exception of those lying near the cut surface or near the periphery of the clump of cells.

RESULTS

After trying a series of fixatives (Susa, Kaformacet, Zenker, Zenker with formalin, phosphate buffered formalin 10 % (Lillie), Gendre, Carnoy) it was found that intravital fixation with 95 % alcohol was the most suitable method, as a careful uniform fixation of precipitation type was thereby obtained (Baker 1958) with well preserved nuclear structure and picture of the Nissl bodies. The neutral reaction of this fixative must also be mentioned as an advantage. The unavoidable shrinkage was found to be very uniform from one animal to the next, and was checked by measurements of cell size in both experimental groups. No significant difference was found between the two groups.

A histological evaluation of the preparations along the usual lines showed that the nerve cells in the spiral ganglion were more or less uniformly oval, of one size, and with a moderately stained cytoplasm. The basophilic substances were inhomogeneously distributed in this, as the cytoplasm, which was otherwise uniformly stained, contained a number of smaller Nissl bodies

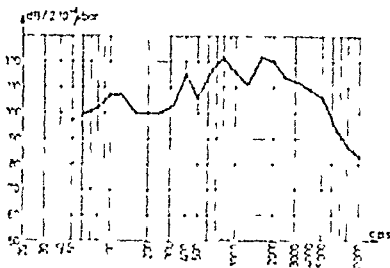


Fig. 1. Frequency analysis of the white noise.

istic for the given sound effect measured at a distance of 50 cm from the aperture of the acoustic source (Fig. 1).

The animals were placed in a funnel-shaped wooden box of the following dimensions: base 5 × 55 cm; distance from animal to acoustic source 40 cm. The bottom of the box consisted of a metal net resting on wooden strips. The animals were under urethane anaesthesia which was so deep that Preyer's reflex was abolished. The animals were exposed to the noise for a period of 30 minutes to six hours, followed immediately by intravital fixation with 95 % alcohol after perfusing the vascular system for ½ minute with physiological salt solution at body temperature at a perfusion pressure of [illegible] cm of water. After perfusing for one minute with alcohol, which as experience shows runs slowly through the vascular system, the animals were decapitated as rapidly as possible, the bulla was opened, then the cochlea apically, the stapes luxated and the whole immersed in 95 % ice-cold alcohol. The duration of the fixation procedure was at most 2 to 3 minutes. After 24 hours the modiolus with the ductus cochlearis *in situ* were prepared under alcohol with the aid of a Zeiss operation microscope. The preparation obtained was fixed for a further 24 hours in ice-cold 95 % alcohol, after which it was taken through to paraffin and the sections cut 10 μ thick in the long axis of the modiolus. The sections were then stained by Einarson's method with gallocyanin chrome alum at pH 1.64 for 48 hours at 18°C. They were then mounted in DPX. The thickness of the section was measured by focusing on the upper and lower surface, the mean value being very nearly 10 μ. The extinction was determined on the section by means of a microspectrophotometer (magnification × 3000). Interference filter lambda nanometer 580 was used. Measurements were made on 2[illegible] cells in each section, at two points in the cytoplasm of each cell. The measuring field was

TABLE 1

Each extinction value is the mean of 50 readings in 25 cells two in each cell A correction has been made for variations in thickness of section

Control animals		Animals exposed to acoustic stress		
Animal no	Extinction	Animal no	Duration of acoustic stress (min)	Extinction
1	0.77	9	30	0.61
2	0.93	10	45	0.64
3	0.77	11	60	0.65
4	0.71	12	60	0.60
5	0.85	13	60	0.53
6	0.79	14	80	0.61
7	0.85	15	120	0.61
8	0.74	16	240	0.61
		17	360	0.55

Mean extinction Control animals 0.801 Animals exposed to acoustic stress = 0.613 The difference is significant

intensities just below the pain threshold The result of choosing a high noise level therefore should be to affect an extensive region of the spiral ganglion without the necessity of applying a peak load over one frequency range with consequent rapid destruction of the sound receptor—the organ of Corti This procedure should permit greater freedom with respect to preparation and measurement Further it was considered a rational procedure to give the entire amount of noise in one dose so as to be able to establish the time of commencement of changes in the content of RNA following the acoustic stimulation just as it is regarded as significant to be able to exclude prior destruction of the organ of Corti and consequent interruption in the production of impulses

Traumatic artefacts were guarded against by fixation in alcohol for 24 hours before the microdissection (Cammermeyer 1961) It was found important to exclude as many of the processes of histological preparation as possible Decalcification could be avoided by careful microdissection as a result of embedding in paraffin the very thin walled bony capsule surrounding the ganglion and constituting the greater part of the bony substance of the modiolus almost atomizes on cutting and the paraffin stops it from damaging the ganglion cells Even the best decalcifying agents such as formic acid sodium formate using Kristensen s (1949) method or Jenkin s fluid (Pearse 1960) have been found to cause uncontrolled bleaching of the preparations as well as obliteration of the picture presented by the Nissl bodies As a rule a certain proportionality can be reckoned with between the hydrogen ion concentration and the time of decalcification on the one hand and the

gli m spirale gleich nach Aufhör der Lauteinwirkung fand man signifikanten Herabgang in der zytoplasmatischen basophili nach Färbung mit Gall cyanin chromalaun a m Einarson Lel pH 1 6 J keine Proportionalität zwischen der Länge der Geräuscheinwirkung und dem Grade der zytoplasmatischen Basophili wurde gefunden

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IMBALANCE, NYSTAGMUS AND DIPLOPIA IN WALLENBERG'S SYNDROME

Clinical analysis of a case and post mortem examination

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Disequilibrium, nystagmus of various types, and diplopia are prominent features of Wallenberg's syndrome. In the case reported here the general condition of the patient was good and allowed an extensive series of examinations from the onset of the disorder. The study revealed several interesting features:

(1) 2–3° horizontal rotatory nystagmus to the left occurred when the eyes were open.
(2) The direction of nystagmus was reversed (from left to right) on eye closure.
(3) After the first weeks caloric nystagmus could often be elicited only when the eyes were open.
(4) During the third to fifth months the spontaneous nystagmus was largely replaced by irregular eye movements in all directions of gaze.
(5) Vertical divergence of the eye axes was present in all fields of gaze.

The patient died suddenly from heart failure 7 months after the onset. Autopsy showed a typical lateral infarction in the right side of the medulla.

The reversal of nystagmus and the disappearance of caloric response on eye closure are not explainable on the basis of commonly accepted principles.

Case Report

Engineer, aged 53.

He was admitted on August 30th, 1961, with vertigo, nystagmus, diplopia, and slurred speech which had developed the day before. Arterial hypertension had been observed for 10 years but no previous signs of cerebral infarction had been noted.

Examination on admission. The patient was well oriented and alert. The blood pressure was 215/130 mm Hg. There were no clinical signs of heart failure. He suffered from frequent hiccups.

Neurological examination showed the following abnormalities:

The right pupil was slightly larger than the left. There was slight ptosis on the right side. The right corneal reflex was absent.

The patient preferred to lie on his right side or on his back with his head rotated and slightly flexed towards the right. There was marked nystagmus, imbalance and diplopia (see special reports).

Na tinnitus and no hearing loss was present

The right vocal cord and the right side of the palate were paretic though he was able to swallow. The taste sensations were considerably impaired on the right side of the tongue.

Perception of pinprick and heat/cold was greatly impaired on the right side of the face and almost totally absent on the left half of the body.

There was a slight right-sided dysmetria in the finger to nose and knee to heel tests.

The muscles were possibly somewhat weak but the reflexes were normal.

Sweating was absent on the right side of the face and possibly on the shoulder.

[illegible] estimated heart size [illegible] corresponding to [illegible] body surface area. Normal heart [illegible]. The thoracic aorta was of normal length and width and there were no signs of pulmonary stasis. [illegible] left deviation and [illegible]

Blood electrolytes normal values

Urine analysis [illegible]

Creatinine clearance [illegible]

[illegible] There was a marked improvement during the ensuing weeks. The hiccups disappeared. The [illegible] sensation increased in the lower parts of the face and to some extent in the body. The palatal paresis [illegible] and the loss of taste [illegible]

The [illegible] dysmetria [illegible] a few weeks after the onset and the nystagmus, imbalance and [illegible] decreased (see special reports).

The patient was discharged on November [illegible]

After further improvement he resumed full-time work in February 19[illegible]. In March [illegible] heart failure developed and he died suddenly on March [illegible]

[illegible] (Mller [illegible])

The heart weighed [illegible] g, the myocardium of left ventricle was hypertrophied. There were [illegible] of recent infarction of [illegible] the myocardium. The [illegible] were of normal width. Lungs, liver, spleen and kidneys showed [illegible] congestion [illegible]. Furthermore there was marked pulmonary [illegible] bilaterally in the thorax.

In the neck the right vertebral artery was narrowed by atherosclerotic plaques [illegible] its lumen was visible in all sections however. In [illegible] the artery was occluded by a [illegible] at about [illegible] The basilar artery was moderately narrowed by atherosclerosis. The left vertebral artery and the cerebral arteries showed [illegible]

A cystic softening (Fig. [illegible]) was found in the right medullary region at a level corresponding to the lower part of the right inferior olivary nucleus. It was of triangular shape in the sections. The edge of the triangle extended towards the midline. In a [illegible] direction [illegible] the middle olivary level (Fig. [illegible]) the infarct extended [illegible] and [illegible] approached the lateral part of the floor of the fourth ventricle. The infarct extended [illegible] to the upper levels of the olive.

The cystic lesion had a characteristic histological picture with [illegible] cell reaction and gliosis in the vicinity.



Fig. 1. Infarction in the right lateral medullary region, (*a*) at the caudal level of the olivary nucleus, (*b*) rostrally to the mid olivary level.

No tinnitus and no hearing loss was present.

The right vocal cord and the right side of the palate were paretic, though he was able to swallow. The taste sensations were considerably impaired on the right side of the tongue.

Perception of pinprick and heat-cold was greatly impaired on the right side of the face and almost totally absent on the left half of the body.

There was a slight, right-sided limb dysmetria, most noticeable on the finger-to-nose and knee-to-heel tests.

The right limbs were possibly somewhat weak, but the reflexes were normal.

Sweating was absent on the right side of the face and possibly on the shoulder.

Radiology: Estimated heart volume 1020 ml, corresponding to 470 ml/m² body surface area. Normal heart configuration. The thoracic aorta was of normal length and width, and there were no signs of pulmonary stasis. *Electrocardiogram*: Left deviation and/or coronary insufficiency.

Blood chemistry: normal values.

Urine analysis: 0.1–1.1 ‰ albumin.

Creatinine clearance: Filtration 75 ml per minute.

Course: There was a marked improvement during the ensuing weeks. The hiccups disappeared. The impairment of sensation decreased in the lower parts of the face and to some extent in the body. The palatal paresis diminished and the loss of taste improved.

The limb dysmetria subsided a few weeks after the onset, and the nystagmus, imbalance and diplopia decreased (see special reports).

The patient was discharged on November 2nd, 1961.

After further improvement he resumed full-time work in February 1962. In March 1962 signs of heart failure developed and he died suddenly on March 22nd 1962.

Autopsy (Moberg)

The heart weighed 600 g, the myocardium of left ventricle was hypertrophied. There were no macroscopic or microscopic signs of recent infarction or fibrosis in the myocardium. The ostia were of normal width. Lungs, liver, spleen and kidneys showed pronounced congestion, both chronic and acute. Furthermore, there was marked pulmonary edema and bilateral hydrothorax.

In the neck the right vertebral artery was narrowed by atherosclerotic masses; a lumen measuring about 1 mm in diameter was visible in all sections, however. Intracranially the artery was occluded by an old thrombus about 1 cm long; a tendency to recanalization was visible histologically. The basilar artery was moderately narrowed by atherosclerosis. The left vertebral artery and other cerebral arteries showed no major changes.

A cystic softening (Fig. 1a) was noted in the right medullary region at a level corresponding to the lower part of the right inferior olivary nucleus. It was of triangular shape in the sections. The edge of the triangle extended towards the midline. In a more rostral portion (rostrally to the mid-olivary level, Fig. 1b) the infarct extended dorsally and in a small area it approached the lateral part of the floor of the fourth ventricle. The infarct extended rostrally to the upper levels of the olive.

The cystic lesion had a characteristic histological picture with fat granule cell reaction and gliosis in the vicinity.



Fig. 1. Infarction in the right lateral [illegible] ry region (a) at the caudal level of the olivary nucleus (b) rostrally to the mid-olivary l

The infarction destroyed a typical retroolivary region involving (in summary) the spinocerebellar and spinothalamic tracts, reticular nuclei, the spinal trigeminal nucleus and tract, the nucleus ambiguus, the tractus and nucleus solitarius etc. The lateral part of the infarction involved the restiform body. The right medial and the spinal vestibular nuclei were not destroyed but possibly involved, the limits of the lesion were particularly difficult to establish in this region.

No infarct could be seen in the left side of the medulla and no signs of infarction were noted in the pons, cerebellum or other parts of the brain. The spinal cord was not available for examination.

Equilibrium

At the onset of the illness there was a marked dizziness and disequilibration; he was unable to sit up in bed without support. The vertigo increased when the head was turned to the left. The dizziness gradually decreased and the balance improved, so that after 2–3 weeks he was able to sit unsupported, though he still had a sensation of unsteadiness and imbalance. On occasion, notably when he closed his eyes and tried to sleep, he experienced a very distressing sensation, i.e. a marked revolving movement of the bed or a sensation of rotation within the head.

Examination on October 3rd showed no dysmetria of the limbs and no other abnormalities of isolated voluntary limb movements.

Six weeks after admission he began to walk, and during the subsequent weeks he learned to walk without support. After discharge he was able to go from his home to the hospital without assistance. At examination on November 23rd he had a slightly staggering gait. The disturbance of gait was much more pronounced when his eyes were shut; he walked with a wide base, the steps were uncertain and he tended to reel to the right. He was unable to stand on either leg alone even with his eyes open. Romberg's test showed a slight falling tendency.

Considerable concentration and effort were often necessary for maintenance of equilibrium, particularly after movements of the head. The imbalance thus continued to be disturbing.

At the last examination, about 6 months after the onset, slight but disagreeable disequilibration persisted.

Comment

There was a marked disproportion between the slight dysmetria of the (right) limbs and the severe disturbance of equilibrium. The limb dysmetria disappeared after a few weeks but the disorder of gait persisted to some extent throughout the observation period. (The entire symptomatology differed from that observed after injury of a cerebellar hemisphere as described by Holmes 1917.)

The disorder of gait and the limb ataxia are generally treated as a single entity in the literature on Wallenberg's syndrome, and comparison with earlier cases is therefore difficult. Imbalance appears, however, to be the

dominating symptom Some limb dysmetria persists in most patients but it is less disabling than the disequilibration (Currier *et al*, 1961) Disequilibration (without limb ataxia) such as exhibited by our patient a few weeks after the onset of the disease is apparently an unusual feature

Fisher, Karnes & Kubik (1961) described 16 cases of Wallenberg's syndrome They reported several different varieties of anatomic localization in the medulla in four cases they observed an associated cerebellar infarction Cerebellar ataxia of gait and stance as well as of the limbs was not related to lesions of the cerebellar hemisphere or the spinocerebellar tracts but correlated well with involvement of the restiform body Dizziness with or without nystagmus seemed to be unrelated to vestibular nucleus damage The clinico pathologic correlations were however, offered with considerable reservation A detailed clinical analysis was for various reasons impracticable

Nystagmus

Methods

The eye movements were recorded with the use of an electronystagmographic technique (Schott & Meyer) whereby the displacement of the corneoretinal potentials corresponding to eyeball movements is registered The tracings were taken with an electroencephalograph modified and converted for the purpose (Preber 1956) Extensive recordings (including spontaneous and positional nystagmus caloric and optokinetic tests and cupulometry) were made on about twenty occasions between Sept 1st and Dec 7th 1961 The last examination was performed on March 5th 1962 The most interesting results are presented in this report

With D C recording (electrodes placed in the lateral canthus of the palpebral fissure) it is possible to determine the direction of gaze behind closed lids A deviation of gaze (ocular deviation) to the right is recorded as an elevation of the base line and vice versa The recorded aberration from the base line is roughly proportional to the deviation of gaze from the straightahead direction The original base line is determined with the subject's eyes open and the gaze directed straight ahead

Direction of nystagmus

The rapid component of the nystagmus was invariably directed towards the side of the lesion (right beating) when the eyes were closed With the eyes open left beating nystagmus dominated see below These two types of nystagmus were very marked during the first weeks and the reversal of nystagmus on opening (or closing) of the eyes was often very conspicuous (Fig 2 first and second tracing)

The effect of opening (or closing) the eyes was studied chiefly with control of ocular position in the manner described by Hallpike Hood & Trinder (1960) The patient was instructed to look (through closed eyelids) at his finger held at arm's length before his eyes and to gaze at the finger on

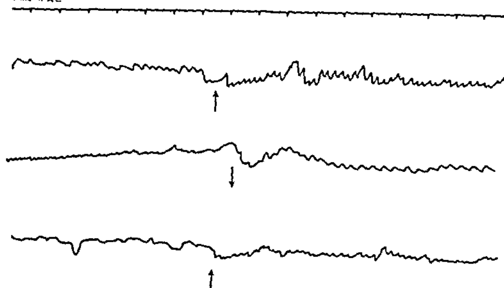


Fig. 2. Sept. [illegible]. Nystagmus to the right is recorded with the eyes closed; when the eyes are opened (↑) it is reversed to left beating nystagmus (1st tracing). Nystagmus to the left (eyes open) is reversed to right beating nystagmus on eye closure (↓) (2nd tracing). The patient tries to look at his finger (held [illegible] to the left) before and after opening (↑) of the eyes. Irregular eye movements are replaced by left beating nystagmus (3rd tracing).

opening his eyes. Ocular deviation to the left was often recorded on eye opening (the deviation was also studied by D.C. recording). The left beating nystagmus was apparently enhanced by this deviation (and the right beating nystagmus occurring on eye closure was increased by ocular deviation to the right). The deviation was, however, often slight; moreover, reversal of nystagmus was observed to occur even when there was 3° nystagmus to the left with eyes open (and 2-3° nystagmus to the right with eyes closed). Ocular deviation therefore does not account for the reversal.

On several occasions no nystagmus was recorded (but only slow irregular eye movements) when the subject looked to the left behind closed lids (Fig. 2, third tracing). Opening of the eyes gave rise to left beating nystagmus.

The reversal of nystagmus was much less obvious after the first weeks (both kinds of nystagmus were weaker) and no nystagmus was often recorded when the eyes were closed even on occasions when left beating nystagmus was present with eyes open.

Nystagmus to the left

The nystagmus was very marked during the first weeks. With eyes open there was a 2-3° horizontal rotatory left beating nystagmus, sometimes with a vertical or oblique component. The horizontal component dominated. It decreased in amplitude and became less constant during the following weeks, although a slight deviation of the gaze to the left was, as a rule

sufficient to bring on nystagmus. The intensity of the nystagmus varied considerably from day to day and even during the course of a single examination. During the third month and later it disappeared periodically and only irregular eye movements were observed (see below).

In the first weeks after the onset the nystagmus decreased when the head was turned to the right (the side of the lesion) and increased in frequency when the head was turned to the left and, occasionally, when it was placed in the head hanging position. Nystagmus episodes of the types recorded in paroxysmal nystagmus (Preber & Silfverskiold 1957) were at no time observed and the dizziness induced by head movements was apparently rather mild.

Nystagmus to the right

Horizontal right beating nystagmus occurred on fixation of an object to the right (eyes open). It was mostly frequent and of low amplitude (sometimes it was replaced by left beating nystagmus). The amplitude of the right beating nystagmus increased (and the frequency decreased) on eye closure and it was particularly during the first weeks present when the eyes were directed forwards (2° nystagmus); occasionally right beating nystagmus of low amplitude persisted when he tried to direct his eyes to the left, fixing a finger through closed eyelids. (Voluntary ocular deviation to the left was relatively well maintained when he closed his eyes; he stated that he felt ocular deviation to the right less well.)

The right beating nystagmus behind closed lids was also recorded in the headhanging position and in the left head position. It was less pronounced when the head was turned to the right. In addition nystagmus to the right was recorded in darkness with the eyes open but closed eye studies in light were preferred, the experimental conditions were easier to control. We are, however, fully aware of the fact that the effects produced by eye closure are somewhat different from those caused by darkness.

Caloric tests

The superadded induced nystagmus (in Hallpike's caloric test) was influenced by eye opening just as was spontaneous nystagmus (see Direction of nystagmus). For instance, at recording on September 5th 1961 the spontaneous right beating nystagmus (with closed eyes) persisted after stimulation of the right ear with water at 30°C, but on opening of the eyes the direction of nystagmus was very strikingly reversed. At another examination the same day the spontaneous right beating nystagmus was enhanced by stimulation of the left ear with water at 30°. On opening of the eyes, this intense nystagmus disappeared.

At *later periods* a picture resembling that described by Preber & Silfverskiold (1960) was recorded on several occasions. There was no (or only weak) spontaneous nystagmus. Caloric left beating nystagmus did not appear (after 14°C stimulation of left ear or 30°C of right ear) when the eyes were

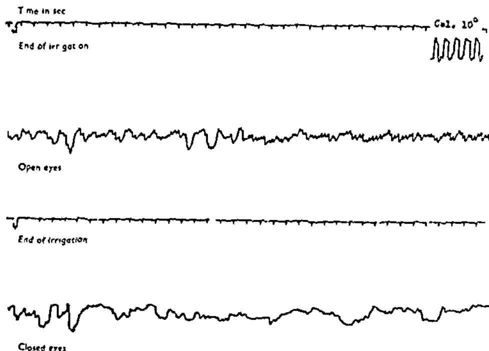


Fig 3 Nov 1961 Caloric tests Stimulation of the left labyrinth (44°C) in both tracings Nystagmus to the left is recorded when the patient's eyes are open (upper tracing) The record shows no nystagmus when the eyes are closed only slow irregular horizontal eye movements are apparent (lower tracing)

closed but when they were open intense nystagmus resulted (Fig 3) Moreover the caloric right beating nystagmus was weak or absent on several occasions but was of normal intensity when the eyes were open The ocular deviation which accompanied intense caloric nystagmus appearing on opening of the eyes (cf above) was evident in several recordings However ocular deviation (towards the rapid nystagmus component) cannot have been more than partially responsible for the occurrence of nystagmus since the latter was observed even when such deviation was slight or absent An additional study was conducted There was no spontaneous nystagmus at the examination Stimulation of the left ear with water at 30°C elicited (1) no nystagmus when the eyes were closed (2) no or very weak nystagmus when the patient attempted to look (through closed eyelids) at his finger held in the straight ahead line (3) distinct nystagmus when he opened his eyes and fixated the finger no definite ocular deviation was recorded during this study

Nausea (vide Behr Preber & Silfverskiold 1955) was not produced by caloric stimulation of either ear —Coughing resulted from caloric stimulation of the left but not the right ear ear cough is generally ascribed to a vagus reflex (via the auricular nerve) this reflex was evidently abolished on the right side (and possibly hyperactive on the left, the ear cough was much less pronounced after about two months)

Comment

Nystagmus or directional preponderance to the contralateral side occurs after unilateral lesions of the vestibular system Barré (1927) and Carmichael *et al* (1956) studied medullary syndromes of various types and their findings are in accordance with this rule Bilateral horizontal nystagmus more marked to the side of the lesion has been observed, however by Wallenberg (1922) and others Fisher *et al* (1961) found that nystagmus could be present when the inferior or medial vestibular nuclei (and the medial longitudinal fasciculus) were not affected but Crosby (cited by Currier *et al* 1961) was of the view that rotatory nystagmus pointed to involvement of these nuclei Rotatory nystagmus was common in the series of Currier *et al*

Electronystagmographic recording seems not to have been employed in the studies of Wallenberg s syndrome In our case the records revealed that the marked left beating (contralateral) nystagmus present with open eyes was replaced by right beating nystagmus when the eyes were closed In the later phases of the illness spontaneous nystagmus was frequently absent from the records and the disturbance of caloric response (nystagmus was not elicited when the eyes were closed) resembled that found in certain pontine lesions by Preber & Silfverskiold (1960) see their discussion

The various features of the observed nystagmus cannot be explained on the basis of commonly accepted principles Earlier clinical pathologic and experimental observations of lesions in the medulla the restiform body or in various parts of the cerebellum fail to shed any light on the underlying mechanism At autopsy of the present case no lesions were found in the left half of the medulla The damage was confined to areas commonly involved in lateral medullary infarctions (Fisher *et al* described the typical infarction as wedge shaped extending from the lateral medullary surface just behind the olive dorsally and medially to approach the floor of the 4th ventricle) The significance of the various lesions in the network of vestibular connections located in these areas is however obscure

Irregular Eye Movements

A few weeks after the onset of the illness peculiar irregular movements of the eyes were observed They were particularly marked during the third month

The eyes on fixation of a stationary point showed arrhythmic concomitant movements of irregular amplitude Although small rapid oscillations dominated larger movements were also present The horizontal eye movements are recorded in Fig 4 there were in addition vertical oblique and rotatory movements The rotatory movements sometimes showed a fast component The irregular movements showed otherwise no obvious rapid phase They were observed in all fields of gaze but nystagmus episodes often occurred when the patient looked to the left and sometimes in the right ocular position (During nystagmus episodes the large eye movements were

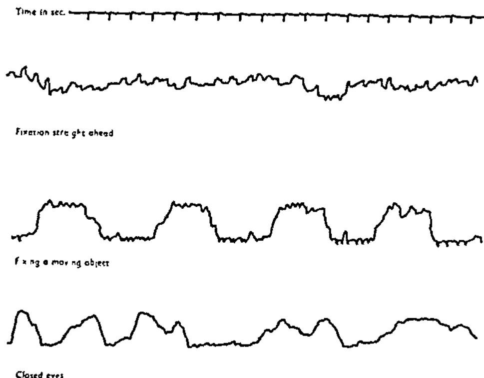


Fig. 4. Nov. 1961. Fixation of a point straight ahead. Irregular eye movements (1st tracing). Pursuit eye movements (fixing an object moving from the left of the midline to the right and then back again). The irregular eye movements are diminished; there is right beating nystagmus of low amplitude in the right position of gaze, slight uncharacteristic oscillations in the left position (2nd tracing). Closed eyes. Only slow, large eye movements are recorded (3rd tracing).

less apparent; a similar stabilization of gaze was seen during caloric nystagmus.)

The movements decreased somewhat on monocular fixation. Correction of the vertical divergence (with a prism) was not followed by objective or subjective improvement.

The rapid movements largely disappeared from the records on eye closure (Fig. 4). The recording of the eye movements was, however, sometimes disturbed by a fine flutter or tremor of the eye lids when the eyes were closed.

Pursuit gaze movements (tracking a moving object) were performed with precision (only minor oscillations were recorded, Fig. 4). There was no obvious "over shooting" of gaze (of the type described by Cogan, 1954) with rapid change of fixation point; this was evident, for instance, during the calibration procedure.

The patient noticed rhythmic oscillations of the images (corresponding to the intense nystagmus) in the first weeks after the onset of the illness. Later he reported irregular movements of the objects—including small rapid torsions. The movements occurred principally on fixation of a stationary

object There was a subjective improvement at the beginning of the fourth month The images were now more steady The irregular eye movements continued however, and he was able to feel these movements

The irregular eye movements were not detectable on examination after about 5 months

Comment

The irregular eye (gaze) movements associated with fixation were more apparent after a few weeks when the nystagmus had diminished and become episodic They were fairly constant in all directions of gaze Several other features distinguished them from the nystagmus the absence of rapid phase the lack of rhythm and the irregularity in direction velocity and amplitude

The irregular rapid eye oscillations had one feature in common with the left beating nystagmus the recorded (horizontal) movements disappeared or decreased on eye closure

The disorder has not been reported in earlier descriptions of Wallenberg s syndrome, and cannot readily be classified The movements were too chaotic to be designated as nystagmoid jerks Chaotic eye movements characterize opsoclonus a very rare condition of obscure origin encountered in certain severe cases of encephalitis opsoclonus was originally described by Orzechowski (1927) subsequently by Cogan (1954) and others the eye movements were apparently more striking (rapid oscillations of large amplitude) than those observed in our case

Irregular small synchronous eye movements appear after bilateral section of the vestibular nerve (Ford & Walsh 1936) They are due to slight movements of the head and cease when the head is held still This feature distinguishes the condition from that observed in the present patient the irregular eye movements in Fig 4 for instance were recorded when he was lying still on a couch In the case observed by Ford and Walsh objects seemed to jump before the patient s eyes when he was walking (the vestibulo ocular reflexes were abolished) The present patient stated that he was seldom disturbed by the ocular symptoms when walking about in the streets Movements of the eyes (and head) in his various activities tended to stabilize the images The movements of the image were most apparent when he tried to fix a stationary object

Vertical Divergence of the Eye Axes

During the first four months the patient was distressed by double vision which decreased somewhat when the head was tilted to the right

Ophthalmologic examination on September 27th 1961 Vision RE 1 0 (−1) diplopia in all directions of gaze the image of the left eye was slightly below and to the right of the right one the vertical distance between the images increased somewhat with downward gaze No specific weakness of eye movements was noted The visual fields were normal (red and white) Fundi Slight arterial narrowings

The slightly oblique, vertical diplopia (with the upper image in a slightly tilted position) remained unchanged during the first weeks. Two months after the onset the diplopia disappeared temporarily when fixation was attempted. *The patient stated that a single image was obtained when the gaze (fixation) was directed from one object to another, though double images reappeared after a few seconds fixation.*

Ophthalmologic examination on November 23rd 1961 (Ryberg). Position of images is described above. Eye posture examined with Herschel's prism: the visual axis of the *right eye was directed downwards (left over right 2° in all directions of gaze)* and slightly outwards; the left eye was used as the leading eye.

On fixation the eye axes were aligned on the fixation point for a few seconds. Movement to a new object was not necessary; fixation when changing from monocular to binocular vision (one eye covered and uncovered) had a similar effect.

Comment

The diplopia in this case was due to a predominantly vertical concomitant divergence in all directions of gaze. German authors (Oloff & Korbsch 1926 and others) use the term *Hertwig Magendies Phanomen* to designate vertical divergence of the eye axes. It was first described by Magendie (182.) as follows: *L'oeil du côté blessé est porté en bas et en avant, celui du côté opposé est fixé en haut et en arrière, et par conséquent dans une position directement opposée à l'oeil opposé.* Section (in rabbits) of the cerebellar peduncle, pons or the lateral part of the medulla produced this picture. A similar disorder is called skew deviation in the British and American literature: the homolateral eye is turned down and inward while the contralateral eye goes up and out. In the present case, however, the homolateral eye was turned down and slightly outward, the picture thus differing to some extent from the characteristic skew deviation. A vertical divergence with or without lateral deviation of the eyes may be produced by clinical or experimental lesions in various parts of the vestibular system or in the cerebellum (*vide* Oloff & Korbsch). The many investigations since that of Magendie have failed to clarify the mechanism of the phenomenon.

Double vision is a fairly common feature of Wallenberg's syndrome, particularly during the first weeks. Earlier authors have diagnosed various kinds of ocular muscle palsy and in several reports the disorder has been attributed to vestibular or cerebellar lesions, skew deviation etc. (*vide* Louis-Bar 1946, Currier *et al.* 1961, Fisher *et al.* 1961). The descriptions are too brief for a comparison with the present picture.

ZUSAMMENFASSUNG

Vertigo, Nystagmus und Diplopie sind oft wichtige Teilsymptome bei Wallenbergs Syndrom. In der Literatur sind keine eingehende Untersuchungen dieser Phanomene zu finden, es gibt aber verschiedene Varianten des Bildes. Wir haben einen Fall mit

ausgesprochenen Symptomen untersucht die allgemeine Kondition des Patienten war gut, und hat schon von Anfang der Krankheit eine Reihe von Untersuchungen ermoglicht Er war verhaltnismassig jung (43 Jahre) und hatte fruher keine Zeichen von einem cerebralen Infarkt

Die bei dem Syndrom gewohnlichen Zeichen eines rechtseitigen lateralen, medullaren Infarktes waren vorhanden ipsilaterale Schlundparese, dissoziierte Sensibilitatsstorung der rechten Gesichtshalfte und Analgesie und Thermanasthesie der linken Korperhalfte Die Dysmetrie der rechten Extremitaten war leicht und schnell vorubergehend

Wahrend der ersten Wochen wurden eine ausgesprochene Gleichgewichtsstorung und auch ein Nystagmus beobachtet bei offenen Augen ein 2 3° horizontalrotatorischer Nystagmus nach links, der beim Augenschliessen in einen 2 3° Nystagmus nach rechts uberging

Es bestand weiter eine Diplopie, die auf eine vertikale Divergenz der Augenachsen in samtlichen Blickrichtungen zu beziehen war

In spateren Perioden wurde der Nystagmus schwach und episodisch Unregelmassige (horizontale, vertikale und rotatorische) Augenbewegungen lagen bei Fixation in allen Blickrichtungen vor Kalorische Reizung bei geschlossenen Augen produzierte in vielen Untersuchungen keine Nystagmusreaktion bei offenen Augen entstand eine lebhafte kalorische Reaktion

Der Patient starb plotzlich nach 7 Monaten (Herztod) Die Obduktion zeigte einen typischen Infarkt im lateralen rechten Teil der Medulla oblongata

Die Umkehr der Schlagrichtung des Nystagmus and das Ausbleiben der kalorischen Reaktion bei geschlossenen Augen konnen nicht durch die bisher allgemein akzeptierten Grundsatze erklart werden

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ON THE MICROPHONIC EFFECT OF THE CRISTA

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The microphonics of the cochlea and of the crista are important for three reasons (1) They demonstrate that by the stimulation with sound the various parts of the labyrinth vibrate (2) By the parallelism between the voltage of the microphonics and the excitability of the organ of Corti and the crista (3) They can give a better insight into the problem of transformation of the mechanical energy into electric energy by the inner ear With regard to (3) there is a discussion of the hair hypothesis of de Vries Kuiper demonstrated that this hypothesis is not right, as the facts cannot be explained by the pulling at the hairs But two important facts remain and require explanation the double frequency of the lateral line organ in the fish and the superposition effect This phenomenon in the pigeon is discussed It occurs when a low and a high frequency component are presented together to the ear

For many years my pupils Bleeker Vrolijk and Ubbens made in close collaboration with the physicist de Vries an investigation of the microphonic activity on the labyrinth of the pigeon The results were published in three thesis and in a number of articles in *Acta Oto Laryngologica* (1949 1951 1955 1949 1951, 1953) The microphonic activity of the crista was demonstrated and described for the first time by Bleeker & de Vries (1949) It was obvious to give this phenomenon the same name as was chosen by Adrian (1931) for the now so well known effect of Wever & Bray (1930) The results were confirmed by van Eyck (1951) who in many experiments did also later excellent work on the crista effect It is a most interesting phenomenon especially from a theoretical point of view The physiological importance of the cochlea effect is very doubtful This seems to be still more the case with the crista effect for this is a reaction on a non adequate stimulation of the crista by sound In these experiments it was always a pure tone stimulation The phenomenon appears only under special circumstances when an opening is made in the bony canal When sound is presented to the ear there are also vestibular reactions, deviation and nystagmus of the head In birds these reactions are much more striking than the movements of the eyes This is the reaction of Tullio (Huizinga 1935)

There is a great conformity between the microphonic effects of cochlea and crista in the pigeon The greatest sensitivity for the cochlea as well as for the crista was found between 600 1200 Hz for the crista at about 900 Hz

This conformity also becomes evident from the experiments on fatigue by Bleeker and by van Eyck An extensive examination was made by Ubbens These experiments are difficult to perform and we found great variation in the results One of the causes may be the direction in which the sound is

applied it is difficult to make it always quite the same. It was settled again that fatigue increases in proportion to the amplitude. For these experiments intensities of 75 and 105 db were mostly used. These intensities are not high, the threshold of the Tullio reaction being high, as was described with van Eunen, Huizing & Huizinga (1943). The action on the crista proceeds in the same way as the action on the cochlea. This is an argument that fatigue in the organ of Corti and in the crista has the same localisation, probably in the specific sensory cells.

Fig. 1 demonstrates the course of the fatigue of the crista which corresponds exactly with the course of the fatigue of the cochlea. This is an experiment in the crista posterior of pigeon 1119 with a frequency of 430 Hz and an intensity of 105 db. At *1* the crista effect is shown 1 sec after the beginning of the stimulation, at *2* we see the microphonic activity after 1 minute and at *3* after 4 minute. The amplitude of the microphonic effect diminishes gradually from 37 µV to 26.6 µV. Then the stimulation is stopped and after a rest of 2 minutes the same stimulus is given again. We see from *4* that there is a perfect recovery, the microphonic activity being exactly the same as at *1*.

The presence of these microphonics gives us three important facts.

(*a*) The sensulae in the labyrinth vibrate at the same frequency as the pure tone stimulus, which is interesting for the theories of hearing.

(*b*) The microphonics give a clear insight into the activity of the labyrinth. This is generally known for the microphonics of the cochlea, which in numerous experiments were already used for this purpose. The same holds also for the crista effect. This can clearly be demonstrated by a comparison of the threshold curve of the Tullio reaction and the equal response curve for a certain potential level of the microphonic effect of the crista. There is a very strong parallelism between these two curves, as is demonstrated by Fig. 2. Here the threshold of the Tullio reaction was determined easily by the just perceivable head deviation evoked by the pure tone stimulus after fenestration of the horizontal canal. The greatest sensitivity was found at ~900 Hz, both for the Tullio effect and for the crista effect.

(*c*) *Perhaps the microphonics may give us a better insight into the stimulating mechanism in the inner ear, especially as to the important and very* topical question: how does the mechanical electric transducer work. We only have to read the proceedings of the last symposium of the Collegium O.R.L.A.S. in Padua (1960) on this subject to get an idea of how difficult it is at this very *moment to give the right answer to this question.*

The circumstances for our investigations on the pigeon were very favourable because de Vries discovered in Groningen the microphonic activity of the lateral line organ in fishes (*Acerina cernua*), which phenomenon was described for the first time by de Vries, *Jielof & Spoor (1952)*. This microphonic effect of the lateral line organ was studied later on in detail by his pupil Kuiper (1956), who gave an excellent survey and also a criticism of the haircell theory of de Vries. By a careful analysis Kuiper proved that this theory cannot be right. *But the remarkable results of the experiments of*

de Vries are still there and require an explanation. Now after the death of de Vries it seems adequate to give a survey of the most important points of all his work. We will confine ourselves to two points which are of special interest for item (c): the haircell theory of de Vries and the superposition effect, which is now for the first time described in otological literature.

The tragedy of our time, the specialization which proceeds farther and farther, implies that we know more and more about less and less. Scientific workers on the labyrinth in general occupy themselves only with one part of the labyrinth, the acoustical part or the vestibulum. Most of them are working either on human beings or always on the same type of animal. In the enormous literature on the labyrinth one will find only a few publications in which work on one part of the labyrinth has inspired the work on the other part. A striking example is our Nobel Prize winner von Békésy (1953). One of his brilliant discoveries is that the mechanical stimulation in the cochlea is caused by shearing forces. He got the inspiration for these experiments by the work of von Holst (1950) on the utriculus of fishes. Of course we need not be astonished at such a result, the epithelium of the different sensulae having the same origin. It therefore can be expected that the principle of the mechanical stimulation is the same. Anyhow, von Békésy showed us once more the great importance of comparative physiology. The work of von Holst is very important for the otologists.

Shearing forces are probably also the adequate mechanical stimulation of the crista. There is not only a deviation of the cupula during a stimulation but also a slipping of the cupula over the crista, as was demonstrated by Dohlman & Wilstrup (1950). The same mechanism was found by de Vries in the lateral line organ. Direct observations of the movements of the cupula showed clearly that there was a deviation as well as a displacement of the whole organ. This displacement is probably the adequate stimulus, again also shearing forces. Now shearing forces mean bending of the hairs, an old conception, e.g. of Maxwell (1923) and even of none other than the great Breuer (1891).

The sensulae in the lateral line organ of fishes have the same architecture as the cristae in the internal ear of the higher animals. The microphonic activity is studied by alternating water currents of different frequencies, the mechanism is exactly the same as the stimulation of the cristae in the pigeon by sound. It seems logical to assume that the mechanism of the stimulation of the sensory cells must be the same.

In Groningen we started with the piezo electric hypothesis. By the deviation of the cupula in the crista by the endolymph and in the lateral line organ by a water current, there is also some deformation. As a result the pressure side of the cupula is stretched and the other side is compressed. This may give rise to a piezo electric effect. But this could not be the right explanation, because in the lateral line organ the greater part of the cupula can be removed without a corresponding decrease in the amplitude of the microphonic effect.



Fig. 1. Fatigue of the crista. Pigeon 1119

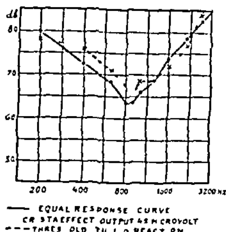


Fig. 2

This experiment of de Vries is of great theoretical interest. In the lateral line the greater part of the cupula can be removed without loss of function of the crista. This experiment is not applicable to the crista in the labyrinth in higher animals, since after manipulation on the cupula there is a total loss of the function of the crista. The presence of the microphonics indicates that after removal of the greater part of the cupula in the lateral line there is still a remarkable physiological function. The bending of the hairs, however, is still possible in this experiment (also the pulling on the hairs as was assumed for some time).

There is another argument against the piezo-electric hypothesis. This is the important question of the energy relation. In the piezo-electric hypothesis the sensulae of the inner ear are supposed to have the role of transformers which passively change mechanical energy into electric energy. In that case the electric energy can never be greater than the mechanical. Von Békésy has proved, however, that in the cochlea the electric energy is greater than the mechanical. De Vries found the same in the lateral line organ.

There is a very remarkable difference in the microphonic effect of the crista and of the lateral line organ. In both cases we measure in the vicinity of the haircells an alternating electric current. *In the crista this current has exactly the same frequency as the stimulating sound, whereas in the lateral line organ the alternating current has the double frequency of the vibration applied.* Any theory on the stimulation of the sensulae should consider this fact and take it into account.

The double frequency in the lateral line organ was the starting point of the haircell theory of de Vries. He assumed that the voltage of the microphonic effect depends on the pulling on the hairs. Fig. 3 is a schematic drawing of a lateral line organ and shows what happens in the examination of the microphonic effect. In *1* we see the cupula, a gelatinous structure as in the semi-

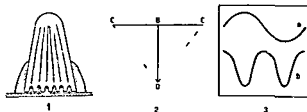


Fig 3 See text

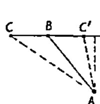


Fig 4 See text

circular canals of the labyrinth resting on a layer of sensory cells with hairs. The to and fro movement makes these hairs stretch twice at each vibration as shown at 2. CB is the amplitude of the cupula, the stretching effect on the hair being twice the maximum as indicated by OC and OC¹. In *3* the movement of the cupula is indicated by *a*, the microphonic effect has the double frequency as indicated by *b*. The double frequency must be interpreted as two negative peaks.

De Vries assumed that at both sides of the cell membrane of the sensory cells a potential difference is found, as is the case in many living cells. The inside is negatively charged as compared with the outside owing to a difference in concentration of ions at either side of the membrane; the negative ions are larger in number at the inside of the membrane and so are the positive ions at the outside. By pulling on the hair at the top of the cell a leak is produced and there will be a current in and around the cell. This current is supposed to stimulate the nerve fibres.

Another important experiment of de Vries was also an argument for the hair hypothesis. The cupula in the lateral line organ can be displaced passively. Fig. 4 is a schematic representation of the movement of the hair in case of a displacement. It is clear that when the cupula is displaced laterally to B so that at the vibration CC¹ the cupula does not pass the equilibrium position, the hair is only stretched once in the position AC. And indeed in these experiments it was found that the double frequency of the lateral line organ had changed into the single one. By a constant displacement as in Fig. 4 *the two negative peaks disappear alternately by a forward and backward* displacement of the cupula, when care is taken that the constant displacement is larger than the amplitude of the vibration.

De Vries explained the fact that in the ear this frequency doubling does not occur by the inclined position in respect to the direction of the vibration. So the situation corresponds with that of Fig. 4. But the microscopical examination of the labyrinth shows that this supposition is not right.

Another argument for the hair theory was the superposition effect. The microphonic activity of the crista presents a linear function, the magnitude of the effect increasing proportionately to the intensity of the sound. For not too large amplitudes the voltage of the microphonic effect is proportional to the amplitude of the crista. The superposition effect is caused by a non-linear function, which was also discovered for the first time in the lateral line organ.



Fig. 5. Superposition effect in the lateral line organ (after Kuiper)

This effect is produced when a pure tone stimulus of high frequency vibration with a small amplitude is superimposed on another one with a low frequency and a large amplitude. The high frequency has only a weak effect on the hair, but according to the hair theory this effect must be much greater when the hair is in the inclined position as a result of the vibration with large amplitude. In the positions OC and OC' (Fig. 3) the effect of the high frequency stimulus is amplified by the lower one. At the moment when the cupula passes the equilibrium position OB there must be no amplification. Theoretically this superposition effect was assumed as a consequence of the hair hypothesis. Later on it was proven in experiments by de Vries.

Fig. 5 gives the representation of such an experiment on the lateral line organ. Curve 1 shows the voltage of the vibration with the large amplitude, curve 2 is the voltage of the high frequency. The superposition effect is clearly demonstrated by curve 3, the resulting voltage curve when both frequencies are applied. The higher frequency component is amplified in the negative peaks, at the top is the zero point: here is no amplification.

As already mentioned, this superposition effect seemed in the beginning a good support of the hair hypothesis, but the analysis by Kuiper of the results of a great number of experiments demonstrated that they cannot be explained by the hair hypothesis. It was made plausible by him that this non-linear effect has its origin in the sensory cells themselves and that it does not result from a mechanical stimulating arrangement.

Kuiper, Ubbens and de Vries demonstrated that this interesting phenomenon also exists in the labyrinth of the pigeon and the cat. Ubbens made an examination of the superposition effect in 38 pigeons, both for the cochlea and the crista. He always found an amplification as well as a zero point of the high frequency component. In order to demonstrate this phenomenon it is necessary that the frequency of the higher component differs considerably from the lower one: mostly the higher frequency was taken several times greater.

There is a large difference in the amplification in the cochlea as compared with that in the crista. In different animals the values are also varying. In the lateral line organ of the fish the amplification is often 6 ×. The amplification in the cochlea of the pigeon is small, the maximum was 1.7 ×. The amplification in the crista is more common, it is 3 × and in some cases it was even 8–10 ×. There is also a great difference in the localization of the zero point.

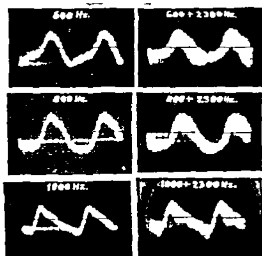


Fig. 6. Superposition effect in the cochlea, pigeon 1124.

It is very seldom at the top of the curves. In the microphonics of the cochlea the zero point is mostly on the upward part of the curve, for the crista, on the contrary, it is on the downward part of the curve. This is demonstrated in Figs. 6–8.

The phenomenon is not the result of interference, as was proven with many experiments. The amplification regularly appears totally independent of a change of the frequencies. Care must only be taken that there is a large difference between the low and the high frequency component. Fig. 6 is an example of such an experiment with the microphonics of the cochlea in pigeon 1124. For the high frequency the same value of 2300 Hz was always used, whereas the lower frequency had various values, 600, 800 and 1000 Hz. The shape of the curve remains the same in the stimulation with both frequencies, the amplification being on the downward curve.

Fig. 7 is the result of an experiment with pigeon 109. The upper part shows the photographs of the microphonics of an experiment on the cochlea. The result is the same as in Fig. 6, the zero point being on the upward part of the curve, whereas on the downward part the amplified portion is seen.



Fig. 7. Superposition effect of the cochlea and of the crista, pigeon [illegible]

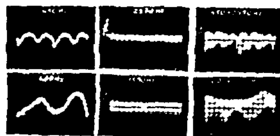


Fig. 8. Superposition effect of the crista, pigeon 1098.

The curves below are the microphonics of the crista horizontalis of the same pigeon. First we see the crista effect evoked by a stimulation of a tone of 450 Hz. There is a strong deformation of the sinus, as is often seen in the crista effect. The high frequency was 2100 Hz. The last curve shows the superposition effect in a stimulation with both frequencies. The time base frequency of the oscillograph was adjusted so that the zero point can be seen 4 times; it is always at the top of the downward part of the curve. The amplified portion is at the place of the negative top. The output can be calculated easily; the amplification here is 3.1 ×.

Fig. 8 shows another experiment on the crista posterior of pigeon 1098. In the upper curve the superposition effect is seen with the frequencies 450 and 2370 Hz; in the lower curve the stimulation is with 600 Hz and 1550 Hz. The effect is seen 4 times in the upper curve and 2 times in the lower one. The amplification here is 3.2.

In his famous work von Helmholtz (1896) also discussed the overtones and the combination tones. They are the consequence of a non linear function of the ear. There is much literature on the question of whether the localization of the non linear function is in the middle ear or in the inner ear. For von Helmholtz and others it was in the middle ear; later investigators localized it behind the stapes. By experiments with extirpation of the tympanic membrane in 6 pigeons Ubbens demonstrated that the non linear function *which is the origin of the superposition effect is localized in the labyrinth.* Of course there was a diminution of the cochlea and of the crista effect in this experiment. Van Lunen, Huizing and Huizinga had already found that after extirpation of the eardrum the threshold of the Tullio reaction was elevated to ± 28 db. Ubbens found the same for the microphonics; he found values of 26–32 db. But the superposition effect was still there and the character was quite the same.

RÉSUMÉ

Les microphoniques de la cochlée et de la crête sont importantes pour trois raisons: 1. Elles démontrent que pendant la stimulation par un ton pur il y a une vibration de tout le labyrinthe. 2. Par le parallélisme entre le voltage des microphoniques et l'excitabilité de l'organe de Corti et de la crête. 3. Elles peuvent donner une notion comment dans l'oreille interne l'énergie mécanique est transformée en énergie élec-

trique En relation avec 3°, l hypothèse de de Vries de la cellule ciliée est discutée Kuiper a démontre que cette hypothèse ne peut pas etre juste, les faits ne peuvent pas etre expliqués par la traction au cil Mais deux faits importants restent pour etre expliqués la double fréquence dans les organes de la ligne latérale chez le poisson et l effet de superposition Cet effet est discuté chez le pigeon, il se produit quand une fréquence basse et une fréquence haute sont présentees à l oreille interne

ZUSAMMENFASSUNG

Die mikrophonischen Effekte der Cochlea und Crista sind wichtig aus drei Grunden 1) Sie beweisen, dass bei akustischer Stimulation das ganze Labyrinth vibriert 2) Der Parallelismus zwischen Voltzahl vom mikrophonischen Effekt und Empfindlichkeit des Organes von Corti und der Crista 3) Sie konnen ein tieferes Verstandnis geben, wie im Labyrinth die mechanische Energie in elektrische umgesetzt wird In Beziehung auf 3) wird die Haarhypothese von de Vries besprochen Kuiper hat angegeben, dass diese Hypothese nicht richtig sein kann die Tatsachen konnen so nicht erklart werden Aber zwei wichtige Tatsachen bleiben und warten auf eine Erklarung die doppelte Frequenz im Seitenlinieorgan beim Fisch und der Superpositionseffekt Dieser Effekt bei der Taube wird besprochen Er entsteht bei Einwirkung von einer niederen und einer hoheren Frequenz

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VIBRATORY TINNITUS AND PALATAL MYOCLONUS*

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1. Two female patients with vibratory tinnitus and spontaneous palatal myoclonus are reported. One male patient with vibratory tinnitus and voluntary palatal myoclonic movements is described.

2. The tinnitus was heard only when the palatal muscles and salpingo-pharyngeus muscles contracted and the tubal orifices are closed. The tinnitus can be heard both by the patient and by other persons.

3. No common etiology could be determined.

4. No specific treatment has been delineated.

Fowler (1939) has divided head noises into two groups: vibratory tinnitus and non-vibratory tinnitus. He defined them as: vibratory tinnitus is caused by actual vibrations from any source reaching the end organ of the cochlea—non-vibratory tinnitus is caused by factors other than vibratory. Non-vibratory tinnitus is due to lesions or factors implicating or stimulating the neural acoustic structures. The site of origin may be central or peripheral. Vibratory tinnitus occurs when actual mechanical vibrations occur within the head and are heard by the individual.

Non-vibratory tinnitus is frequently noted accompanying sensori-neural hearing loss of almost any etiology. It may be found in the absence of a hearing loss, related to arteriosclerosis or other cerebral vascular disease, to intoxication states, to metabolic disorders, to cervical spine abnormalities and many others. Vibratory tinnitus is observed less frequently by the clinician and only rarely is he able to hear the patient's head noise also.

One source of vibratory tinnitus has been observed in association with palatal myoclonus. Pulec & Simonton (1961) recently surveyed the literature finding references to 168 cases of vibratory tinnitus and palatal myoclonus and added two cases which they had studied. The present report will describe three patients with vibratory tinnitus and palatal myoclonic contractions.

In two patients the vibratory tinnitus was related to and only appeared with involuntary palatal myoclonus. In the third patient the vibratory tinnitus was also related to and only appeared with the palatal myoclonic movements which were deliberately made by the patient.

The nature, causes, and lesions of clonus are mentioned briefly. A clonus

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or repetitive jerks is a rhythmic series of involuntary muscular contractions induced by stretching of the tendon —The presence of true clonus indicates that the reflex arc is hyper excitable, owing to the withdrawal of the regulating or restraining influence normally exerted through the pyramidal tracts (Purves Stewart 1947) Myoclonus [consists of] sudden quick contractions of an individual muscle usually not producing any movement at a joint (Rad Korohn 1955) Myoclonus can be caused by vascular lesions of the brain stem in which the thalamo olivary tract is injured (Merritt 1955) Some myoclonic movements appear to be disturbances at a low level of the nervous system Myoclonus may be produced by lesions in the neighbourhood of the olive Myoclonus is a symptom which may be produced by a variety of lesions and in some cases the nature of the underlying disorder of function is still obscure (Brain 1947) Palato pharyngo laryngoculo dia phragmatic myoclonus is characterized by involuntary rhythmic movements of the soft palate pharynx larynx and diaphragm and sometimes other muscles It may be unilateral or bilateral Movements may vary from 50 to 240 per minute The condition has been associated with lesions of the olivo dentoru brometen cephalic pathways Causes [are multiple sclerosis or vascular lesions A certain percentage of cases are said to be on a psycho genic basis (De Jong 1950) Nielsen (1946) wrote that lesions of the posterior longitudinal bundle the central tegmental fasciculus the inferior olives and the reticular formation have been found anatomically in the presence of palatal myoclonus It appears that the varieties of pathology and their loci vary considerably and that several etiologies may be ascribed to this phenomenon

Not all vibratory tinnitus has as a component palatal myoclonus nor can the tinnitus be heard always by the patient and by an observer

Case Reports

Case 1

This patient s tinnitus appeared within twenty four hours from the time when she experienced a whiplash injury This injury has been described as the damage sus tained by the neck structures where the body in propulsion comes to a sudden stop or when the body is suddenly propelled forward and/or backward and or to the side (see Ref Symposium on Whiplash Injuries)

On July 11 1959 Mrs H S aged 3[illegible] was a passenger in her husband s automo bile This car while at rest was struck in the rear by another car The following morning she noticed ear noises She also complained of pain in the neck shoulders and back Diathermic treatments controlled this eventually and the pain subsided The tinnitus persisted She said that her hearing seemed impaired because of the competition of the head noises which sounded to her like a pulsation

She had been seated in the right front seat at an angle facing the driver The im pact caused a sudden disturbance of anatomic relationships between the head and trunk It was determined subsequently that her head and cervical spine had moved first into left lateral extension and then into right lateral flexion

She was referred on September [illegible] 1[illegible] The otological examination revealed

normal appearing structures. No active disease or gross pathology was observed. Pure tone audiometry demonstrated air conduction thresholds of all frequencies for each ear between 10 db and zero db. Speech hearing was normal for threshold and for discrimination.

An auscultation tube was interposed between one ear of the patient and one ear of this observer. A repetition of ticking or clicking sounds was heard. It was noted that the clicks were synchronous with movements of the entire soft palate. The epipharynx was exposed with a nasoscope and movements of the soft tissues adjacent to the tubal cushions bilaterally and the palate were seen whenever the tinnitus was heard both by the patient and by the observer. Sometimes isolated clicks appeared. At other times there were series of clicks with only brief pauses between. No motion of the tympanic membranes was observed.

Robaxin[8] was prescribed in daily divided doses. She was re-examined on November 1, 1959, five months after the accident. Her tinnitus was still present and the described movements were visible. Both spheno-palatine ganglia were anesthetized with tetracaine hydrochloride 2 %, which failed to modify the movements or the tinnitus.

She was referred for orthopedic consultation. Some abnormality of the curvature of the cervical spine was noted. When flexion of the neck was induced the noises disappeared for a relatively long interval with eventual recurrence. Similarly rotation of the head to the left and to the right with flexion produced temporary abeyance of the tinnitus. She was seen once more in February 1960. The tinnitus and palatal myoclonus were still present. Hearing tests demonstrated normal pure tone thresholds.

Case 2

Mrs. D. H., 41 years old, at the age of 17 years realized that she had ear noise, more pronounced in the right ear, which became louder when she had an upper respiratory tract infection. The sounds have remained constant in character and in frequency and are of continuous occurrence. She said her hearing is "extra good". She denied any history of otic disease or injury.

Her birth was a normal delivery at home. Her growth was normal and she experienced few illnesses and no injuries. She had had rubeola, rubella, chicken pox, and pneumonia. Adenoidectomy and tonsillectomy were performed at 12 years.

In 1941 she was hospitalized with a diagnosis of "exhaustion", which diagnosis was inexplicable to her. No disease being found she recovered from this illness and diagnosis quickly and uneventfully. After 1946 she became the happy mother of nine children. In 1958 she was ill with Asiatic influenza at the time of an epidemic. During her pregnancy of 1957 upon a routine chest X-ray, pulmonary tuberculosis was discovered. She was treated with isoniazid for two years and in May 1961 submitted to a right upper lobectomy. Recovery was uneventful. Her only present complaint is that the perimammary surgical scar is irritated by her brassiere.

Physical examination of the tympanic membranes reveals both appear normal. No spontaneous movement is detectable under low magnification. There is no gross nasal, pharyngeal, or rhinopharyngeal pathology.

The palate moves with a regularity of 80 contractions per minute quite rhythmically. The soft tissues of the epipharynx are seen to move with the palatal contractions, observed by both anterior rhinoscopy and with the nasoscope. The observer, using an auscultation tube, also heard the clicks which appeared when the palate

and the salpingo pharyngeus muscles contracted closing the tubal orifices Talking swallowing, and other pharyngeal activities interrupt the involuntary movements at which times clicking noises are not heard

A hearing aid receiver, used as a microphone, was applied to each ear and the tinnitus was recorded on tape through an amplifying circuit Partial analysis of the sound by means of an oscilloscope reveals that the duration of one click is 1/50th of a second The forms of several sounds were similar but not identical The form of the sound has not been analyzed but it appears to be a complex of frequencies

Case 3

Mr H S, age 26, was examined in August 1961 His complaints relative to the left ear were of about four years duration, consisting of a sense of fullness and also of clicking sounds when he moved the mandible Autoinflation would temporarily relieve the sense of fullness He had had bilateral myringotomies in early childhood In 1958 he submitted to a nasal septectomy and six weeks following this procedure a rhinoplasty was performed all for the purpose of relieving the ear symptoms This hoped for result was not obtained Shortly thereafter a diagnosis of pulmonary tuberculosis was established He was hospitalized and medicated with para amino salicylic acid and isoniazid resulting in an apparent cure Because a nasal deformity had ensued following the rhinoplasty he was reoperated upon to correct this in 1960

The ear, nose and throat examination revealed few abnormalities The external nose had symmetry There was a small anterior septal perforation The tympanic membranes demonstrated small scars Both were mobile the left slightly less than the right

Normal pure tone thresholds were obtained audiometrically throughout the spectrum, ranging from 10 db to zero db Paracentesis aspiration of the left tympanum demonstrated that no fluid was present This paracentesis seemed to give him some relief from the sense of fullness

When he deliberately contracted the velum a click was heard by this observer The palate was seen to move upwards and backwards Nasoscopic exposure of the epipharynx revealed that the soft tissues adjacent to the left tubal cushion moved when the palate contracted The tympanic membrane was viewed under low magnification but no movement was noted

These palatal and rhinopharyngeal movements which he produced voluntarily appeared to be identical to those which the previous patients demonstrated involuntarily

ANATOMY

The palate is formed by five paired muscles levator veli palatini tensor veli palatini musculus uvulae glosso palatinus and pharyngo palatinus The muscles incorporated in the rhinopharynx are the Superior constrictor and the Salpingopharyngeus (Gray)

Four muscles have some attachment of origin to the cartilagenous auditory tube These are the levator veli palatini tensor veli palatini salpingopharyngeus and tensor tympani Tensor veli palatini muscle and tensor tympani muscle are innervated by the motor division of Vth cranial nerve The other muscles are innervated through the pharyngeal plexus This plexus is formed by fibers from the superior cervical ganglion of the sympathetic

nervous system fibers from the bulbar portion of the accessory nerve with branches of the glossopharyngeus nerve vagus nerve and external laryngeal nerve Undoubtedly there is appropriate neural intimacy to permit effective coordinated responses of this muscle group for physiological purposes

DISCUSSION

The noise heard by the patients is related to the contractions of the muscles described. The noise is heard by observer noting that the tubal orifices are closed by the action of the salpingopharyngeus muscles. No determination could be made to be able to conclude that the noise is due (1) to the contraction of the muscles only (2) to traction on the cartilage of the auditory tube (3) to closure of the tubal orifice or (4) to movement of the tensor tympani muscle and its effect on the ossicular chain. No movement of the tympanic membrane was observed but this failure might be because of insufficient magnification of the drum head. Since there was no means whereby the palatal contractions and those of the salpingopharyngeus muscle could be isolated from each other no conclusion was reached if only one is the responsible element. Nor is there an opinion how exactly is the noise generated.

No common etiological elements were noted. The phenomenon started in patient 1 after a cervical spine whiplash injury. This trauma involving the soft and osseous cervical and shoulder structures could initiate stimuli traversing through any of the neural routes thereby stimulating the nerve complexes of the pharyngeal plexus and of the Vth nerve. The stress of the auto accident and the injury could be reflected psychologically in this motor manner although the immediacy of the appearance of the vibratory tinnitus might preclude this.

Patient 2 experienced the noise as far back as she could remember knowing that it was present at the age of 17 and possibly much before this age. The only clue is that of an adenoidectomy and tonsillectomy when she was 12 years old. Possibly the surgery or the position of the head and neck while under anesthetic the trauma to the pharyngeal and rhinopharyngeal musculature or her (unconscious) efforts to alleviate her postoperative pain provoked the palatal myoclonus which pattern having been established has persisted.

Patient 3 produced muscular movements deliberately to relieve him of a feeling of fullness in the left ear. No explanation was found to clarify the basis of this symptom.

The spontaneous coordinated contractions of these several muscles have been identified as palatal myoclonus and concepts of clonus and of palatal myoclonus were cited earlier in this paper. The symptoms of case 1 followed a whiplash injury with insult to the cervical structures. Case 2 might have suffered some cervical trauma while under the general anesthetic for her tonsillectomy. This is sheer speculation. Case three's contractions were deliberately provoked. There is nothing to indicate that there is any high

central nervous system pathology in these patients nor is there a suggestion that these instances of clonus are identical to the clonus observed in organic neurological disease

TREATMENT

No specific treatment appears available Explanation frequently satisfies the physician and sometimes allays the patient s anxiety about the condition There seems to be no general therapeutic measures for these cases One recognizes that therapy will be individualized if and when each underlying mechanism can be ascertained

Structural trauma as in the instance of the cervical spine whiplash injury may yield to orthopedic means If there is sufficient evidence to consider that the cause rests on psychological factors psychotherapy may be desirable

SUMMARY

Fowler has classified head noises into two groups vibratory tinnitus and non vibratory tinnitus Vibratory tinnitus is caused by actual vibrations from any source reaching the end organ of the cochlea — non vibratory tinnitus is caused by factors other than vibratory

Some vibratory tinnitus can be heard both by the patient and by other persons Instances of this kind have been observed in association with palatal myoclonus The latter phenomenon is recognized as usually rapidly repeated spontaneous and involuntary contractions of the velum and sometimes of the superior constrictor and salpingopharyngeus muscles A click is heard when the muscles contract and the orifice of the auditory tube is closed However the exact source of the sound has not been identified

In three patients pure tone audiometry established normal thresholds for all frequencies No active otorhinolaryngological disease was discovered No neurological disease was found

It is suggested that palatal myoclonus may differ from other myoclonic manifestations observed in varieties of central nervous system diseases

No specific treatment is recommended Therapy may necessarily be individualized consistent with the underlying cause of the palatal myoclonus in each patient

ZUSAMMENFASSUNG

Fowler hat Ohrgeräusche in zwei Gruppen eingeteilt vibratorische und nicht vibratorische Das vibratorische Ohrgeräusch wird verursacht durch tatsächliche Schwingungen die von irgendeiner Quelle das Endorgan der Cochlea erreichen während nicht vibratorische durch andere Faktoren als Schwingungen verursacht werden

Manche vibratorischen Ohrgeräusche sind für den Patienten sowohl als für andere Personen hörbar Fälle dieser Art sind in Verbindung mit Gaumen Myoclonus beobachtet worden Dieses letztere Phänomen besteht aus gewöhnlich sich schnell wiederholenden spontanen und unwillkürlichen Kontraktionen des Gaumensegels und manchmal des oberen Konstriktor und Salpingopharyngeus Muskeln Ein

„Click" ist hörbar, wenn die Muskeln sich kontrahieren und die Tuben-Öffnung verschlossen wird Aber die genaue Quelle des Geräusches ist nicht bekannt.

Drei Patienten hatten normale Audiogramme für alle Frequenzen. Keine aktive otorhinolaryngologische Erkrankung wurde entdeckt und keine neurologische Pathologie gefunden Es wird angenommen, dass Myoclonus der Gaumenmuskeln verschieden ist von andern myoclonischen Manifestationen, die in einer Anzahl von Erkrankungen des Zentralnervensystems beobachtet werden

Keine spezifische Behandlung wird empfohlen. Je nach der zugrundeliegenden Ursache des Gaumenmyoclonus bei jedem Patienten muss die Therapie individualisiert werden

Report of Case 2 by kind permission of the New York Regional Office, Veterans Administration The opinions expressed are those of the author only and are not necessarily those of the Veterans Administration

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INITIAL AUDITORY ADAPTATION[1]

I. In Normal Individuals

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The purpose of the present investigation was to elaborate an adaptation test for use in clinical routine and to establish normal values so that the test could subsequently be applied in various forms of deafness. Seventy-four normal subjects of all ages were tested. The initial adaptation was measured by the threshold rise of a short tone (30 msec) applied 50 msec after the cessation of a pure tone stimulus (1000 msec). The frequencies of the stimulus tones were 250, 1000 and 4000 cps. The frequency of the test tone was at all frequencies ½ octave above that of the stimulus tone. With this frequency interval the (threshold) shift was observed at stimulus intensities of 50–55 db above the hearing threshold at all frequencies, with increasing age at lower intensities. The threshold rise at intensities 20 db above incipient adaptation amounted to 12–14 db at all ages.

Scope of Investigation

Very marked changes in the sensitivity of the human ear have been observed in various experiments both during and shortly after the end of sound stimulation. Partly due to differences in the techniques by which these sensitivity changes have been studied some confusion exists as to the terminology. However, most authors agree that "fatigue", which was the term of choice in the first experiments, should be reserved for the threshold rising effect of damaging high intensities. The decline in sensitivity caused by low intensity stimulation is generally referred to as "adaptation". This phenomenon also shows changing characteristics in human experiment depending on the technique by which it is studied.

From animal experiments it seems quite obvious that at least two forms of adaptation exist.

Matthews (1931) studied the adaptation in single stretch receptors of muscles. When a stimulus is applied to such an end organ an initial burst of high frequency discharge of action potentials is recorded lasting for 0.2 sec.; after this the frequency rate shows a slow decline with time as the stimulation is continued. This decline was termed adaptation. If the stimulus is removed and reapplied within 1 sec. the initial discharge is still diminished

[1] Aided by a grant fr[illegible]

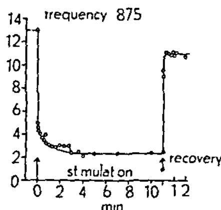


Fig. 1. Action potential of the auditory nerve in relation to duration of stimulation (from Derbyshire & Davis).

the more the shorter the rest period is. This was termed adaptation remainder.

Derbyshire & Davis (1935) in recording action potentials from the auditory nerve in the cat by gross electrode were able to demonstrate a decline in the rate and amplitude of the overall discharge. Within 2 sec the discharges greatly diminished; this was called fast equilibration. Within the next 7 minutes a further decline termed slow equilibration was recorded (Fig. 1).

In view of these animal experiments it is reasonable to assume the existence of at least two types of adaptation, viz. initial fast adaptation and slow adaptation. Now, if an equivalent to the fast adaptation found in animal experiments is to be demonstrated in man, it is obvious that it can only be done by using very short tones or clicks as the phenomenon occurs within 1–2 sec.

Previous Investigations

The initial adaptation in normal individuals measured by the threshold rise of a short tone applied after a known short interval after the cessation of the stimulus tone was studied by the following authors.

De Maré (1939) applied pure tones of frequencies 256, 512, 1024 and 2048 cps with intensities of 44, 66 and 88 db for 3.1 sec and measured the after effect 0.2, 0.4 and 0.7 sec later by means of threshold determination of a test tone of 0.4 sec duration, and in binaural experiments with loudness balance. The effect was studied for other frequencies than that of the stimulus tone. The effect measured immediately after the cessation of the stimulus tone increased with the intensity of the stimulus, the maximum effect being 48 db in loudness balance. The effect was most pronounced at the stimulated frequency and decreased symmetrically above and below that frequency. The effect decreased rapidly (viz. 20 db) in 0.2 sec, after which the decrease went on more slowly.

Luscher & Zwislocki (1947, 1949) used a stimulus pure tone of the frequency 1000 cps at intensities 30–80 db above 2×10^{-4} μb, applied for 400 msec. (Test tone of 20 msec duration at varying frequencies.) The after effect was measured 10–150 msec after cessation of the stimulus tone. The maximum effect was 40 db and the duration 0.2 sec. The magnitude and duration of the after effect increased with the stimulus intensity. The effect was most pronounced at and above the stimulated frequency.

Gardner (1947) studied the adaptation by means of test tones of a duration of 30 msec applied 34 msec after the cessation of a stimulus tone. He found that the after effect decreases asymmetrically around the stimulated frequency, the fall being more pronounced below than above that frequency.

Munson & Gardner (1950) using a pure tone stimulus of the frequency 1000 cps for 400 msec measured the after effect by means of a short tone of a duration of 70 msec. The magnitude of the threshold shift was 15 db.

Harris *et al.* (1951, 1952, 1953) in extensive studies investigated short duration auditory fatigue measured by means of short tones of 30 msec duration for several frequencies. The intensity of the stimulus tone ranged from 30–70 db. Maximum effect was measured as 60 db, the magnitude was found to increase with increasing frequency of stimulus. Recovery was found to be complete within little more than one third of a second.

In detailed experiments on normal subjects Bentzen (1953) studied by means of short tones the dependence of the after effect on the frequency, duration and intensity of the stimulus tone, and mapped out the spread of the effect to frequencies other than that of the stimulated tone. He found that the after effect increases with the stimulus intensity, but is independent of the stimulus duration and the frequency used. In measurements of the after effect for frequencies other than that of the stimulus tone, Bentzen found that it was greatest for the stimulated frequency, less pronounced for the frequencies just above, and least for those just below the stimulated one. Increases in the intensity resulted in a similar distribution, but the number of frequencies affected increased with the intensity.

On the basis of these investigations Bentzen regarded the adaptation as a consequence of stimulation characterized as follows:

1. Its duration is less than or equal to the stimulus duration.
2. It is most pronounced for the stimulated frequency.
3. It is of the same magnitude for all frequencies.
4. It is not accompanied by tinnitus.

Langenbeck (1959) investigated the short duration poststimulatory threshold shift and its recovery by means of electronically controlled signals of noise which were superimposed on a continuous pure tone. He found that the adaptation was complete within 0.2–0.4 sec., and that the recovery time was maximally 0.5 sec. When the stimulus intensity was 80 db, the adaptation was found to be 50 db.

In spite of certain discrepancies in the details of the cited studies, which

are presumably due to differences in the techniques applied the existence of a short duration auditory adaptation provoked by low intensity stimulus has *been proved by these investigations The magnitude of the shift in sensibility* is 10 30 db and the phenomenon dies out within less than 1 sec

As to the site of this phenomenon most of the authors are inclined to localize it to the end organ

Present Investigations

Several authors (de Maré Gardner and Bentzen) proposed the application of a short tone adaptation test in clinical audiology and the purpose of these investigations was to elaborate an adaptation test for use in clinical routine and after establishment of normal values to apply the test in various forms of deafness in order if possible to contribute to the topographical diagnosis in hearing impairment

Furthermore by measuring the adaptation in patients with perceptive deafness it might be possible to obtain more information as to the site of initial adaptation

METHOD

As stimuli pure tones of the frequencies 250 1000 and 4000 cps were used the duration of the stimuli being 1000 msec

The test tone was 30 msec being as short as possible with regard to maintained pitch perception the limit of which is 20 msec The test tone was applied 50 msec after the cessation of the stimulus (At this interval Bentzen obtained the most accurate measurements)

As proposed by Gardner the frequency of the test tone was at all frequencies ½ octave above the stimulus tone thus test tones of frequencies 375 1500 and 6000 cps were used

Apparatus

The apparatus was developed and constructed at Thrige s Research Laboratories It consists of three identical channels Each channel consists of a photo electric switch a generator an electronic switch an amplifier and an attenuator (Fig 2)

The photo electric switch is illuminated through a rotating screen which can be furnished with apertures of varying sizes and forms by which changes in the duration and form of the tones can be controlled Rounded impulse forms were used and noiseless switching was obtained The tone generator was connected to a pair of Beyer earphones

Procedure

The examination was performed in a sound proof room in which both the test subject and the examiner as well as the apparatus were The subject was seated facing the examiner and the control panel was placed so that the subject could not see it

The threshold of the stimulus tone (1000 msec) was first determined for each ear at three frequencies (250 1000 and 4000 cps) Next the threshold of the test tone (30 msec) was determined at 375 1500 and 6000 cps while the stimulus tone was

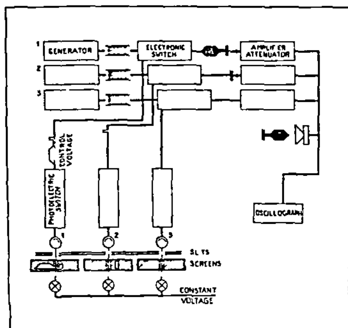


Fig. 2. Block diagram of the entire assembly.

turned off. The stimulus tone and test tone were then delivered at the threshold values at an interval of 50 msec. and the subject was requested to concentrate on the test tone and indicate whenever he heard it (as a click).

The intensity of the stimulus tone was then increased in steps of 5 db. while the test tone remained unchanged at the threshold value until it could no longer be distinguished. It was then increased by 5 db. following which the stimulus tone could again be increased. This sequence was continued until the maximum capacity of the apparatus, 100 db, was reached.

The procedure was then repeated at other frequencies. It proved useful to start at 1000 cps. which usually gives rise to the least difficulties for the subject. The certainty with which the various subjects indicated the results varied to some extent; a few were completely unsuitable as test subjects. The reliability of the results must often be checked by repeated tests. On the other hand, prolonged examination with an excessive number of repetitions tires the subject, so that a greater accuracy is not obtained.

RESULTS

The result of the test for each frequency is plotted in a system of coordinates in which the abscissa represents the intensity of the stimulus tone and the ordinate that of the test tone. The resultant curve is characterized by an initially horizontal path, i. e. the threshold for the short tone remains unchanged at increasing intensity of the stimulus tone. Only when the latter has reached an intensity of about 50 db above the hearing threshold must the intensity of the test tone be increased in order that the subject can hear it. After that the curve rises evenly with increasing intensity of the stimulus tone.

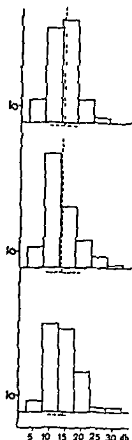


FIG. 5. SA in normal individuals.

250 and 1000 cps the age groups up to 79 can be treated collectively, only in the group 80 or over did the results differ significantly from the others. For the frequency 4000 cps the MSI was lower as early as from the age of 50, and those over that age can be divided into two groups. For the youngest age groups the MSI was identical for the three frequencies.

All the results of the measurements are shown graphically in Fig. 4, giving all frequencies together. The results for the right and the left ear are given separately.

The average SA is listed in Table 2. The distribution appears from the histogram (Fig. 5). It was not possible to demonstrate any influence of age on the SA, for which reason the series is listed collectively for each of the three frequencies. The average increase in the threshold for the short tone at a stimulus intensity of 20 db above incipient adaptation is 13 db. The degree of accuracy of the measurements of this increase is not very high. It must be remembered that for practical reasons the unit of measurement was 5 db, and as related to this unit the measured values were very small.

DISCUSSION

The method of examination is fairly complicated and time consuming and requires both ability and willingness to co operate on the part of the patient. In spite of this and in view of the relatively large unit used in the measurements (5 db) the accuracy of the MS determinations is great as appears from the very close correlation between the values for the right and the left ear. The degree of accuracy is less for the SA because the unit is very large as compared with the threshold shift measured. In the younger age groups the results were identical for the three frequencies. The MSI was found to decrease with increasing age especially as far as the highest frequency (4000 cps) is concerned. This is in agreement with the physiological hearing impairment for this frequency with advancing age. On the other hand this impairment does not influence the SA.

TABLE 2. *MSI and SA in normal individuals*

Confidence coefficient of 95 %

	Frequency cps	Age years	Average db	Standard deviation db
MSI	250	79	52.4	±7.2
		80	38.3	±7.2
	1000	79	56.0	±8.0
		80	39.6	±8.0
	4000	≤49	54.0	±9.1
		69	42.8	±9.1
		70	21.0	±5.2
SA	250		12.8	±4.1
	1000		13.0	±5.2
	4000		14.0	4.7

ZUSAMMENFASSUNG

Es war der Zweck der vorliegenden Untersuchung einen Adaptationstest für den Gebrauch im klinischen Alltag auszuarbeiten und dafür Normalwerte zu ermitteln so dass der Test dann bei verschiedenen Formen von Taubheit zur Anwendung kommen konnte. Vierundsiebzig normale Versuchspersonen jeden Alters wurden getestet. Man ermittelte die anfängliche Adaptation durch Schwellenerhöhung eines kurzen Tones (30 msec) der 50 msec nach dem Ablauf der Stimulierung mit einem reinen Ton (1000 msec) einsetzte. Die Frequenzen der Stimulierungstöne waren 250, 1000 und 4000 Hz. Die Frequenz des Testtones lag in allen Fällen ½ Oktave über der des Stimulierungstones. Mit diesem Frequenzintervall wurde die Schwellenverschiebung bei Stimulierungsstärken von 50 bis 55 db über der Hörschwelle bei allen Frequenzen festgestellt, mit zunehmendem Alter bei geringeren Stärken. Die Schwellenerhöhung bei Stärken von 20 db über der anfänglichen Adaptation erreichte 12 bis 14 db bei allen Altersgruppen.

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SIMULTANEOUS TRANS-TYMPANIC AND ELECTROPHYSIOLOGICAL INDICES OF THE ACOUSTIC REFLEX ACTIVITY IN THE CAT[1]

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The middle ear muscle contractions of the awake cat were monitored simultaneously by changes in cochlear microphonic response and changes in the output of a microphone sealed along with a carrier tone source in the animal's ear canal. A comparison of the two methods showed the cochlear microphonic attenuation caused by muscle contraction to be more sensitive but the difference was often only 10-15 db for stimulus/carrier frequencies between about 1.2 and 2.5 kc. This observation is taken as evidence that the difference in sensitivity of the acoustic reflex of man and cat is not primarily due to differences in the sensitivity of the measurement method employed.

The observed sensitivity of the middle ear muscle acoustic reflex in man (Jepsen 1951, Møller 1961) is considerably less than that reported for some experimental animals (Eliasson & Gisselsson 1955, Simmons 1959). These differences in sensitivity have from time to time prompted the question of whether a true species variability or differences in the sensitivity of the measurement methods are involved. Those who have used various indirect impedance change methods for measurements on man have usually maintained their method to be adequately sensitive and that the reflex sensitivity of experimental animals—measured more directly by attenuation of cochlear microphonic or by EMG studies—reflects species difference, not an increase in measurement sensitivity. However, it was with some prejudice for the opposite belief that this experimenter first employed both types of measurement methods on normal, awake cats. The results of comparing the two on the same animal indicated, however, that the impedance method is, in some instances, almost as sensitive as the more direct electrophysiological determinations.

METHODS

Awake cats with electrodes permanently implanted on the round window and/or in the middle ear muscles were used. Five animals were tested first by conventional methods which have been described elsewhere (Simmons 1959, Simmons, in press) and then as follows. Each animal was fitted with an external ear mould of the type shown in Fig. 1, wherein two Audivox

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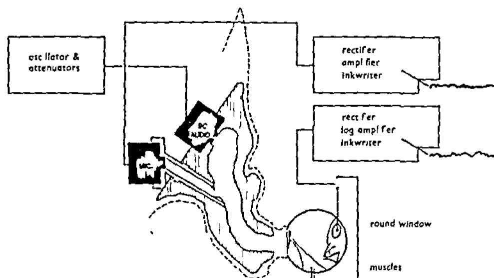


FIG 1 Diagrammatic outline of the experiment's instrumentation The bipolar electrodes shown for muscle recordings were, in reality, located in the contralateral ear Impedance of the 9 C's was 28 ohms at 1 kc, total cavity size was about 1 5 cc A Grass 5P3 amplifier (differential input) was used as a preamplifier for the microphone 9 C

9–C hearing aid receivers were mounted, one acting as a microphone A carrier/stimulus tone was introduced through the other 9–C Its audio output into the cavity was continually monitored by the 9–C microphone, while *that portion of the stimulus transmitted across the middle ear to the cochlea* was monitored by continuous measurement of the cochlear microphonic amplitude appearing at the round window Reflex induced changes in the amplitude of both the 9 C microphone and the cochlear microphonic to a constant intensity tone were observed on an inkwriter, after suitable rectification of the two signals

RESULTS

Comparisons for the various measures of muscle activity were obtained by ipsilateral excitation from three normal animals and contralateral stimulation from two of the three For these five comparisons, the electrophysiological indices of muscle contraction were more sensitive, but occasionally by as little as 10 15 db, depending upon the stimulus/carrier frequency No systematic difference between ipsilateral and contralateral stimulation was noted, though no attempt was made to define the reflex sensitivity by either method in less than 10 db steps

Figure 2 shows the output voltage from the 9–C microphone (top trace) and the cochlear *microphonic output (bottom trace) in* response to the same stimulus tone, in the same ear, at the same time Note that immediately after the 1.7 kc tone was introduced the amplitude from both sources was small, and as muscle relaxation occurred, the amplitudes increased A few seconds

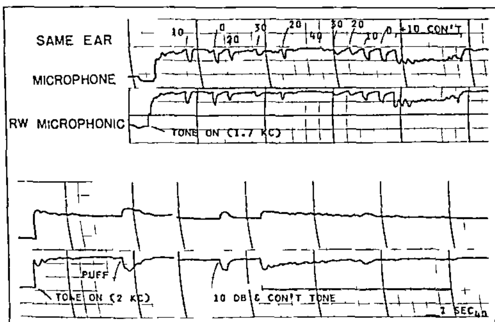


Fig. 2. Inkwriter tracings of 9-C microphone and cochlear microphonic amplitude changes with muscle contractions. In the upper section the responses are to a continuous 1.7 kc tone (SL about 75 db) turned on at the left hand side. The numbers above the 9-C amplitude (upper trace) are relative decibels of sound attenuation introduced through the contralateral ear at the points indicated. In the lower section similar responses for a 2 kc carrier/stimulus are shown.

later after a more stable amplitude was attained tone pulses and then a longer duration were introduced through the contralateral ear causing reflex contractions in the test ear. In the lower two tracings from the same animal the carrier frequency was changed from 1.7 to 2 kc. After the initial on response the first stimulus for muscle contraction was a puff of air introduced into the animal's face and then additional contralateral tonal stimuli.

In Fig. 2 it can be noted that the 9-C microphone response was at times upward (increased voltage output) and at times downward depending upon the carrier frequency. For carrier or combined carrier/stimulus frequencies below about 1 kc and above 3.5 kc no alteration in the 9-C microphone voltage was noted even though muscle contractions monitored by electrophysiological methods were often quite marked. Between these two extremes of frequency 9-C microphone amplitude changes paralleled those of the electrophysiologic measures surprisingly well and at frequencies between about 1.2 and 2.5 kc attained the comparative maximum correspondence of 10-15 db mentioned above.

Fig. 3 shows a typical set of such changes for carrier frequencies between 1 and 7 kc. At the beginning of each line (1, 2 and 3 kc) the tonal stimulus was introduced under conditions similar to those of Fig. 2. Then air puffs

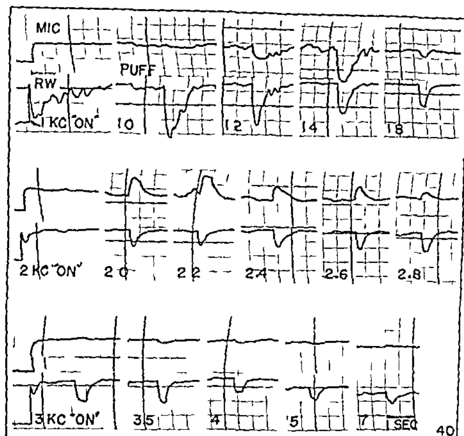


Fig. 3. 9-C Microphone (top trace) and cochlear microphonic (bottom trace) amplitude changes as a function of carrier/stimulus frequency. The first section of each line set shows the 9-C microphone (MIC) and the cochlear microphonic (RW) initial response to introduction of a tone at the indicated frequency. The sets that followed show alterations occurring with muscle contractions elicited by brief (approx. 0.5 sec) puffs of air in the cat's face when the frequency of the carrier tone was as noted. Cochlear microphonic amplitude equals 7.5 db per each chart division. The amplification of the 9-C microphone was constant but not calibrated.

were introduced causing muscle contraction, cochlear microphonic attenuation (lower trace) and the corresponding changes in the 9-C microphone output. While the cochlear microphonic response was always attenuated that from the 9-C microphone was entirely absent at 1 kc, became maximal downward by 1.4 kc, then was reversed near 2 kc, and finally underwent a second much smaller reversal at 3.5 kc before disappearing entirely at higher frequencies.

In addition to such measurements on normal animals, control studies were obtained from these normal animals anesthetized (muscles deactivated) with pentobarbital. No evidence of reflex activity or change in the 9-C microphone output was noted. Measurements were also made on an awake cat whose middle ear muscle insertions had been previously cut and on an additional animal stimulated contralaterally whose other cochlea had been

macerated the stapes fixed in the resulting fibrous reaction. Neither showed the typical fluctuation in the carrier amplitude of the 9 C microphone output. Finally, section of the nerve supply to the pinna in an otherwise normally muscled cat failed to influence the reflex response alterations observed prior to section. The role played by electromyographic measurements in these observations was primarily supportive and chiefly confined to simultaneous and concomitant observations from the contralateral ear, signaling the presence or absence of reflex activity induced by stimulation of the test ear (i.e., in the cut muscle control and anesthesia measurements). In another study (to be published) a good correlation between middle ear muscle EMG activity and attenuation of the cochlear microphonic by muscle contraction has been found.

DISCUSSION

The intent of this communication is to publicize the observation that a so called indirect method of observing middle ear muscle activity compares favorably with the classical electrophysiologic methods at certain stimulus frequencies. The methods used herein were comparatively crude ones which do not justify specificity or a detailed analysis of potential reasons for the rather marked frequency limitations or the presumed resonance peak noted at 1.9-2 kc. The arrangement of the ear insert measuring device allows it to be sensitive to pressure as well as impedance changes and perhaps other factors as well. Pressure or volumetric changes per se, however, when measured in dummy cavity—variably coupled to a condensor microphone—were small compared with the alterations seen with measurements from the cat.

It would seem, even on the basis of these measurements, that the often observed differences in sensitivity of the middle ear muscle reflex between man and cat do not rest primarily on differences in measurement techniques. Whether the difference that quite evidently does exist is a true function of species difference or of certain psychological (behavioral) factors remains not completely clear. Recent studies by the author seem to indicate the degree of habituation to the test environment of the animal to play a major role in determining reflex sensitivity.

RÉSUMÉ

Les contractions des muscles dans l'oreille moyenne du chat éveillé étaient observées simultanément au moyen des changements dans la réponse cochléar microphonique et des changements dans l'émigration électrique d'un microphone scellé avec la source d'un ton qui est aussi le porteur dans l'oreille externe. Une comparaison des deux moyens a démontré l'attenuation cochléar microphonique occasionnée par la contraction musculaire d'être la plus sensitive, mais la différence n'était que 10-15 db pour les fréquences du stimulus porteur entre 1.2 et 2.5 kc. Cette observation était prise pour évidence que la différence dans la sensitivité de la reflexe acoustique entre l'homme et le chat ne résulte pas dans le principe des différences dans la sensitivité de la méthode employée pour gagner les mésurages.

ZUSAMMENFASSUNG

Die Kontraktionen der Mittelohrmuskeln einer Katze in wachem Zustand wurden gleichzeitig auf doppelte Weise überprüft einerseits über ein Mikrophon in der Cochlea und andererseits über ein im Gehörkanal des Tieres zusammen mit einer Trägerton Quelle versiegeltes Mikrophon Ein Vergleich der beiden Methoden ergab eine höhere Empfindlichkeit für durch Muskelkontraktionen verursachte cochleare mikrophonische Abschwächung, doch war der Unterschied oft nur 10 bis 15 db für Stimulierungs- bzw Trägertonfrequenzen zwischen ungefähr 1,2 und 2,5 kHz Dieses Ergebnis deutet darauf hin, dass der Unterschied in der Empfindlichkeit des akustischen Reflexes zwischen dem Menschen und der Katze nicht in erster Linie auf eine unterschiedliche Empfindlichkeit der verwendeten Messmethoden zurückzuführen ist

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SPECIFIC AND NON-SPECIFIC TRAITS OF HABITUATION IN NYSTAGMUS RESPONSES TO CALORIC STIMULI

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In human subjects the electronystagmographically recorded responses to repeated monolabyrinthine caloric stimuli are shown to be influenced by specific (discriminative) processes as well as by alerting (arousal).

The response decline to repeated stimuli is more pronounced with identical stimuli than with stimuli that are of equal average intensity but differ in regard to their quality (cold, warm) and/or localization (right, left labyrinth). This is not due to variations in the general activation level (as reflected in the electrical skin resistance and in the electroencephalogram).

Thus, the habituation process seems to be specifically linked to the direction of the cupular deflexion in the individual labyrinth, or to conscious discrimination between changes in the experimental situation as a whole.

Introduction

In recent investigations it was shown that habituation to repeated identical monolabyrinthine caloric stimuli can be found in the vertigo and nystagmus responses in healthy human subjects (Lidvall 1961 *a* and *b*), as well as in the nystagmus responses in cats (Henriksson *et al.* 1961).

The habituation was thought to be specifically linked either to (1) the direction of the cupular deflexion in the individual lateral semicircular canal (Lidvall 1961 *a*), or to (2) some central mechanism making a distinction between changes in the direction of nystagmus but not between changes in the direction of the cupular deflexion in the individual labyrinth (Henriksson *et al.* 1961).

Since these two hypotheses are controversial to some extent, the present investigation was carried out to elucidate the problem of "directional specificity" in the habituation process. It was also regarded as necessary to follow the general activation level (= the physiological degree of wakefulness, cf. Duffy 1957 and Malmo 1959) during the experimental procedure, since habituation is known to be influenced by variations in the general activation level.

Thus, Mowrer (1934), Wendt (1951), Mahoney *et al.* (1957), Lidvall (1961 *a*), Collins *et al.* (1961, 1962) found that situations which cause alerting (arousal) counteract habituation to repeated labyrinthine stimuli. Further, Crampton & Schwam (1961) noted, in experiments on cats, that the

response decline (RD) in postrotatory nystagmus was associated with a decreasing level of wakefulness as indicated by the EEG. They also evoked a state of continuous arousal by administering repeated electric shocks, but this procedure did not wholly prevent RD. The authors concluded that the reduction of wakefulness is only one of the factors of importance to the habituation process.

MATERIAL AND METHODS

Experiments with paired series of monolabyrinthine caloric stimuli were performed on 32 subjects, all of whom satisfied the primary requirements for selection described earlier (Lidvall, 1961a). Moreover, all cases were excluded where, in relation to the nystagmus response to the first irrigation, there was an increase in the number of *beats in the response to the last irrigation in any of the two first series in the paired series* (see below).

The responses, recorded electronystagmographically, were evaluated *only* with regard to the total number of beats, since this response variable is quite sensitive to habituation (Lidvall, 1961*b*).

Each experiment consisted of eight irrigations (duration 30 seconds, interval 8 minutes). The first four irrigations caused identical stimulations of the labyrinth receptor, since they were performed on the same ear with water at the same temperature. The next four stimuli (the second series of stimuli) were also identical, but differed from the first four stimuli (the first series of stimuli) with regard to either (1) only the labyrinth (right or left, *paired series Type 1*), or (2) only the temperature of the water (30.0° C or 43.2° C, *paired series Type 2*), or (3) both the labyrinth and the temperature of the water (*paired series Type 3*).

Two experiments were made with each subject. The average interval between these experiments was 20 days. Each subject was given only one type of paired series, and then only the same two series, but presented in inverse order at the second experimental session. (For example: In the first experiment, first the right ear was irrigated four times with water at 30°, and then the left ear four times with water at 43.2°. At the second experimental session, first the left ear was irrigated four times with water at 43.2°, and then the right ear four times with water at 30°. This is an example of paired series Type 3.)

The experiments were begun the same number of times with cold as with warm water, and with irrigation of the right as with irrigation of the left ear. Eight subjects were irrigated according to Type 1, the same number according to Type 2, and twice the number according to Type 3. Thus, the total number of experiments was 64, and the total number of the series and irrigations 128 and 512 respectively.

Psychological experiments were carried out on 26 subjects. They had not taken part in any other experiments and satisfied requirements as to otoneurological normality (but had not been subjected to routine caloric tests). Furthermore they had to show a reduced number of nystagmic beats in the response to the fourth irrigation as compared with the first, in a series of 6 irrigations of the same ear with water at 30° C.

The 26 persons were placed at random in two equal groups. Both groups were treated exactly alike up to and including the fourth irrigation. Immediately after the conclusion of the *fifth* irrigation the subjects in *group I* were asked to do, as quickly as possible, a number of multiplications mentally (6 × 17, 7 × 18, etc.). The subjects

in *group II* were informed in good time before irrigation No 5 was begun that, when told to do so, they were to count aloud 1, 2, 3, etc They were asked to count immediately after the irrigation was completed Before the *sixth* irrigation all the subjects in both groups were told You will now probably have an unpleasant sensation , but no stimulus other than the caloric was applied

The number of beats in response to the first fourth, fifth and sixth irrigations were calculated

Measurements of the electrical skin resistance were performed at the same time as the electronystagmographical recordings were made, in 37 out of the 64 experiments with paired series (The fact that the skin resistance was not recorded in all the experiments was due entirely to technical defects and consequently, the loss of data was wholly fortuitous) The measurements were carried out with the aid of a Wheatstone bridge, to which were connected two 1 cm² surface electrodes of chloridized silver, placed on the palmar surface of the second and the fourth finger tips of the left hand The bridge ouput voltage was passed through a pair of relay contacts, converting it into short pulses every 1 5 seconds These pulses were supplied to the pre amplifier of an EEG apparatus and were recorded by one of its writers

Just before the beginning of each irrigation the initial value of the skin resistance was read (in kohms) Then the deviations from the initial value (the pre stimulus level) during the course of the nystagmus response were recorded The maximal reduction was observed (galvanic skin response, GSR) during a period up to and including the first half of the duration of the nystagmus response (It is during this period that the irrigations as well as the maxima of the vertigo and nystagmus responses occur)

Electroencephalography was performed in 52 of the experiments with paired series The recordings were made on two channels with the electrodes placed at C_z 0_1 and C_z 0_2 (i e from the vertex to the left and to the right parts of the occiput according to the ten twenty system see Jasper 1958)

The curves were examined for signs of changes in the degree of wakefulness (cf e g Ostow 1950 and Lindsley 1952)

RESULTS

Nystagmic response pattern of paired series

Before the response pattern is presented it should be recalled that since the *series of identical stimulations were paired in inverse order at the two* experimental sessions with each subject the first series comprised exactly the same stimuli as the second series in the total number of paired series Furthermore in each experiment a shift between non identical stimuli occurred between the fourth and the fifth irrigations Thus if the process of habituation were not affected by this change the habituation curve (constructed on the mean values for all observations regarding the number of nystagmic beats) would continue unbroken from the first to the second series In other words the *transfer* of habituation would be *complete*

Fig 1 shows however that the nystagmus responses have a different pattern There is a decrease in the mean number of nystagmic beats for the responses to the first and fifth irrigations whereas an increase in the mean

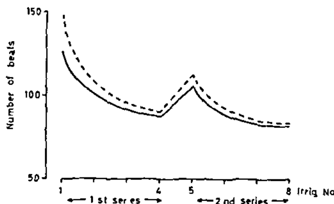


Fig. 1. *Incomplete transfer of habituation.* The mean number of nystagmic beats (computed from 32 observations) are indicated for the first and the last response in the two paired series. Between these points the "negative acceleration" of the habituation curve is indicated. Continuous line: paired series Types 1 + 2. Broken line: paired series Type 3.

number of nystagmic beats occurs on transition from the fourth to the fifth irrigations, i.e. from the first to the second series. Consequently only an *incomplete transfer* takes place.

Furthermore, Fig. 1 shows that this "break" in the habituation curve between the fourth and fifth responses occurs whether the direction of nystagmus is unchanged (paired series Type 3) or not (Types 1 + 2). (This "break" was found in paired series Type 1 as well as in Type 2.)

The means of intra-individual differences between pairs of values were tested for statistical significance (*t*-test). The statistical analyses were performed separately for paired series Types 1 + 2 and for paired series Type 3. The differences between the responses to irrigations Nos. 1–5 and 4–5 were found to be significant (see Table 1).

Transfer of habituation in routine caloric tests

As habituation proceeds the nystagmus responses to successive *identical* stimuli usually become more irregular, i.e. more dysrhythmic (Lidvall 1961 b). Consequently it appears reasonable to assume that if there is a

Table 1. *Statistical significance of differences between nystagmus responses to irrigations Nos. 5–1 and 5–4 in paired series Types 1 + 2 and Type 3 respectively.*

Significance level: *** 0.001 > P; ** 0.01 > P > 0.001; * 0.05 > P > 0.01 (P = prob. [illegible]).

Paired series Type	Differences between irrigations No. 5–1	No. 5–4
Type 1 + 2 *t* value	3.41**	2.68*
Type 3 *t* value	5.39***	3.22**



FIG. 2. Increase in number of cases with moderate to marked nystagmic dysrhythmia (Grades 2 + 3) in responses to successive irrigations in 239 routine caloric tests. The irrigations were always performed in the following order: 30.0° right, 30.0° left, 43.2° right and 43.2° left ear.

transfer effect in the routine caloric test, this should be reflected in a progressive dysrhythmia in response to the four successive *non-identical* stimuli given in this test.

The degree of dysrhythmia was estimated for 239 random routine caloric tests. A four point evaluation scale, previously described (Lidvall 1961 *a*) was used for the purpose.

As illustrated in Fig. 2, the number of nystagmus responses with moderate to marked dysrhythmia (Grades 2 + 3) was found to increase in the responses to successive irrigations. This increase in dysrhythmia is less conspicuous when comparing the responses to the first two irrigations than it is between the responses to the second, third and fourth irrigations.

When all observations on nystagmic dysrhythmia (including Grades 0 and 1) were assessed, a sign test revealed that there was no statistically significant increase of dysrhythmia between the responses to the first and to the second irrigations, but that there was a highly significant (0.001 > P) increase of dysrhythmia between the responses to the third and the fourth irrigations.

Effect of alerting on nystagmus responses

It is well known that dishabituation can be brought about by situations which cause alerting (arousal). It may be nearly impossible, however, to cause alerting without distracting the subject's attention from the ordinary experimental conditions, and it is extremely difficult to answer the question if this distraction of attention in itself influences habituation. The difficulty is that there is no method available to quantify the independent variable of attention.

In the experiments described here, an attempt was made to elucidate the effect of alerting on the nystagmus responses to identical caloric stimuli under at least some control of the attention. For this purpose, the influence of three different experimental situations on the nystagmus responses were compared

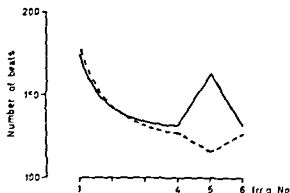


Fig 3 Dishabituation due to alerting The mean number of nystagmic beats (computed from 13 observations) are indicated for the responses to irrigations Nos 1 4 5 and 6 Continuous line represents responses of subjects in group I When they were asked to do multiplications mentally a dishabituation occurred (cf responses to irrigations Nos 5 and 4) Broken line indicates the responses of the subjects in group II These subjects were asked to count 1 2 3 etc during the response to the fifth irrigation which caused no dishabituation Before starting the sixth irrigation both groups were told that this time you may have an unpleasant sensation

The first situation (doing multiplications) was assumed to cause alerting as well as distraction of attention, the second situation (counting "1, 2, 3, ...") to cause distraction but not alerting, the third situation (warning that an unpleasant sensation might occur) to cause alerting and, possibly, slight distraction of attention

All the 13 subjects in group I, who were requested to do multiplications mentally, showed an increase in the number of nystagmic beats in their response to the fifth irrigation This increase in response intensity is highly significant (*t* test) The mean values for the number of nystagmic beats in this experiment are indicated in Fig 3 (cf responses to irrigations Nos 4 and 5 on the continuous line)

In group II which also consisted of 13 subjects, there was no deviation from the expected course of the habituation curve when these subjects were asked to count 1, 2, 3 etc aloud (see Fig 3, broken line)

All the 26 subjects (groups I II) were also told, before the sixth irrigation that they probably might have an unpleasant sensation As is seen in Fig 3 there occurred a response decline in group I, but in group II there was a slight tendency towards an increase in response intensity (statistically non significant)

The first two experimental situations were later analysed in relation to the general activation level (as reflected in the GSR and the EEG), but the third situation was regarded as too complicated for further analysis

It may be mentioned that five subjects were tested twice At the second experimental session they were subjected to a cold stimulus (ethyl chloride was sprayed on to the skin between their toes) during the fifth irrigation of the ear This gave rise to a very vigorous increase in nystagmic response intensity in all five subjects

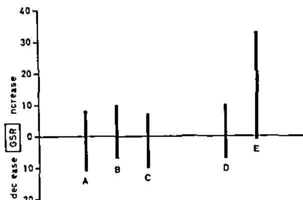


Fig 4 Galvanic skin responses during different experimental situations The figures refer to steps in a scale indicating the number of experiments where there was an increase or a decrease in the GSR In the paired series comparisons were made between the galvanic skin responses to irrigations Nos 1 and 4 (A) between 4 and 5 (B) and between 5 and 8 (C) As is shown in the figure when comparing these experimental situations the frequency of increase and decrease in GSR was approximately the same Counting 1 2 3 (D) did not cause any definite deviation but having to do multiplications (E) brought about a highly significant increase in GSR when this experimental situation was compared (intra individually) with the most vigorous GSR during the experiment with paired series

No definite conclusion can be drawn from the results reported here but it seems that distraction of attention in itself (e g produced by counting 1, 2 3) has no marked influence on habituation and consequently, it seems reasonable to assume that it is the alerting that caused dishabituation to occur in the experiments reported

Control of the general activation level

In the greater part of the experiments with paired series the general activation level was followed by means of the GSR and the EEG Furthermore the experiments were usually finished by additive recordings of the GSR and EEG during the tasks to do multiplications and to count 1 2 3

The *galvanic skin responses* did not reflect the changes in nystagmic response intensity that took place during the experiments with paired series As indicated in Fig 4 there were no statistically significant (sign test) deviations in the GSR either during the nystagmic RD within the series (A C) or during the increase in the intensity of the nystagmic response on transition from the last irrigation in the first series to the first irrigation in the second series (B)

To simply count 1 2 3 did not cause any significant change in the amplitude of the GSR (D) On the other hand when the subjects had to do multiplications mentally there was a highly significant increase in the GSR (E) which confirms the assumption made earlier in this paper that the performance of this task caused alerting

The method was not suitable for measuring the prestimulus activation

level. The values showed a stereotyped tendency to decrease during the experiments with paired series, which was probably due to polarization between the electrodes and/or cumulation of sweat between the electrodes and the skin. This limitation of the technique does not prevent the method for measuring the skin resistance, however, from being adequate for measuring the GSR (cf. Coombs 1938 and Scholander 1961).

The *electroencephalograms* showed no fluctuations of the general activation level *in conformity with the variations in nystagmic response intensity*.

There was an abundant, stable alpha activity throughout the whole experimental session in 16 out of 52 EEG recorded experiments. Blocking of the alpha activity due to the irrigations seldom occurred and was never marked. Beta activity was dominant in the majority of the EEG recorded experiments.

Thus, the general activation level was rather constant during the entire course of the experiments with paired series. This seems reasonable, since *during this experimental procedure the subjects had to co-operate in observing* and describing their subjective responses to the irrigations (cf. Scholander 1961).

DISCUSSION

The finding that the transfer of habituation is incomplete between successive caloric stimuli which differ in regard to their quality and site of application means *that to some extent the habituation process depends upon the identity of the stimuli*.

Since the identity of the stimuli means that the irrigations are performed on the same ear and cause cupular deflexion in the same direction in the lateral semicircular canal, it must be assumed that the habituation shows a trait of selective linkage to the direction of the cupular deflexion in the individual labyrinth.

But the experimental situation as a whole has also to be taken into consideration. The subjects *consciously discriminate* not only between changes in the quality and localization of the stimulations but also between changes in the direction of the vertigo responses. Pairing of Type 1 implies that the subjects notice a change in regard to both the labyrinth stimulated and to the direction of the induced rotatory sensation. Pairing of Type 2 causes a conscious discrimination between differences in the temperature of the water and in the direction of the rotatory sensation. *Pairing of Type 3 causes the* subjects to observe a change in the labyrinth stimulated and in the temperature of the water. It may be assumed that every change of this kind makes the habituation less effective. This hypothesis is an alternative or a supplement to the former one.

The average stimulus intensity was equal in the experiments with paired series. In each experiment, however, the first and the second series must be assumed *to have always differed in regard to stimulus intensity*. Now the question is whether dishabituation can be evoked merely by such a change in stimulus intensity. No experiments were performed to elucidate this

problem, but it seems improbable that the present findings could be explained in this way.

A question of great practical importance is whether the transfer of habituation causes a distortion of the routine caloric test to such an extent as to severely restrict the clinical usefulness of the test. In general the answer to this question is probably "no", but in a minority of cases a clearly progressive nystagmic dysrhythmia in the responses to successive stimulations will obviously call for caution in clinical judgment.

The dysrhythmia of the successive nystagmus responses in the routine caloric test seems to be accelerated. The reason for this "delayed" transfer effect is obscure. It may be due to some characteristic feature of the transfer of habituation, but it should be borne in mind that the method for evaluating the degree of dysrhythmia is far from being exact.

When discussing the progressive nystagmic dysrhythmia in routine caloric tests it has to be pointed out that this finding cannot be explained as due to the interference of secondary nystagmus (cf. Aschan & Bergstedt 1955 and Stahle 1956).

During the last decade some physiological experiments on animals have been carried out in order to study the importance of different anatomical structures to the process of habituation. Specific traits of habituation have been traced to different levels of the brain (cf. Sharpless & Jasper 1956, Hernández-Peón 1959 and Hubel *et al.* 1959). With regard to the habituation to repeated labyrinthine stimulations, Hernández-Peón & Brust-Carmona (1961) claimed that lesions in the pontine tegmentum prevented the RD in postrotatory nystagmus, but that this effect was not obtained by lesions in the cerebral cortex, in the thalamus or in the mesencephalic reticular formation. This finding indicates that the pontine tegmentum is of vital importance to the central control of the responses to labyrinthine stimuli, which seems reasonable in regard to the relative proximity of the lesion to the vestibular nuclei. The problems concerning the anatomical localization of the discriminative features of vestibular habituation are still unsolved.

Under normal physiological conditions habituation is furthered by a decrease in the general activation level (Gastaut & Bert 1961), but counteracted by alerting. It is also known that habituation can be counteracted by conditioning (cf. Humphrey 1930, Davis 1934, Porter 1938, Lehner 1941, Galambos *et al.* 1956, Hernández-Peón *et al.* 1957, 1958, Jasper *et al.* 1958). Therefore it seems natural to regard the responses of the biological organism as the resultant of two fundamentally antagonistic processes, habituation and sensitization, and to assume that both these processes are linked partly to the general activation level and partly to some specific mechanisms.

ZUSAMMENFASSUNG

Es geht hervor, dass bei Versuchspersonen [illegible]
ten Reaktionen auf wiederholte [illegible]

INFRACLINOID ANEURYSM OF THE INTERNAL CAROTID ARTERY AS A CAUSE OF NOSEBLEED

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The case of a 41-year old man experiencing profuse nosebleeds through the right nostril is reported. An infraclinoid aneurysm of the left internal carotid artery opening into the sphenoid sinus was found. No collateral circulation through the anterior communicating artery could be demonstrated in the angiograms. The left internal carotid artery was slowly clamped in the neck to a lumen of about 1 mm. The patient nevertheless suffered recurrent haemorrhages, a new angiogram showed good circulation through the stenosis, and an increase in the size of the aneurysm. The artery was then completely occluded. There was no neurological deficit and no recurrence of bleeding.

There are several reports on intracranial arterial aneurysms as a source of nasal haemorrhage (1–5, 7–21). Most of these cases were encountered in connection with head injuries. However, a report of an additional case seems justified, since it is still not universally recognized that profuse nasal bleeding may in rare instances be caused by an intracranial aneurysm.

Case report

Man, born 1920. Minor skull injury at the age of 5, followed by bouts of migraine persisting into adulthood. Infection of the left middle ear 2 years previous to the present illness.

March 23rd, 1961: sudden profuse haemorrhage from the right nostril. New haemorrhages on April 10th, 19th and 27th, always from the right nostril. The blood loss in some of the haemorrhages was measured and found to be up to 900 g. Rhinoscopy revealed no source of bleeding. On April 27th a ligature of the right anterior ethmoidal artery was performed. May 8th: renewed bleeding.

The patient was admitted to the Neurosurgical Clinic on May 12th, 1961. He stated that before a haemorrhage he always had a feeling of pressure behind the bridge of the nose, then he would hear a snap, and the bleeding would start. He complained of constant tinnitus, which could not be ascertained objectively.

Skull radiograms and right carotid angiography showed no abnormality. Left carotid angiography on May 13th, 1961: infraclinoid aneurysm of the internal carotid artery at the level of the sphenoid sinus (Figs. 1, 2). No filling of the left anterior cerebral or pericallosal artery. On May 16th a second right carotid angiography was performed, with compression of the left carotid artery, but no contrast

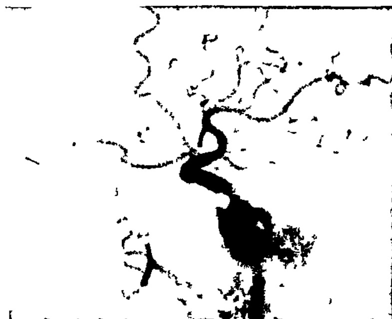


Fig. 1. Subtraction copy of left carotid angiography, lateral view. The aneurysm protrudes from the internal carotid artery into the posterior part of the sphenoid sinus.



Fig. 2. [illegible] lateral view of left carotid angiography [illegible] aneurysm [illegible] into the sphenoid sinus.



Fig. 3. Second left carotid angiography showing an increase in the size of the aneurysm protruding into the posterior part of the sphenoid sinus. Good intracranial circulation. Cf. Fig. 2.

was seen in the left anterior cerebral or middle cerebral arteries. Consequently an immediate left carotid ligature was thought too dangerous and it was decided to use a Crutchfield clamp (C). Meanwhile the patient had a new profuse haemorrhage on May 17th. A clamp was ordered and was applied as soon as it arrived on June 1st 1961. The clamp was slowly constricted over a period of a week; the tinnitus changed but persisted to some degree. It was thought wise not to occlude the artery completely in view of the poor collateral circulation and it was calculated that the lumen of the artery in the clamp had been narrowed to 1 mm by the end of the week. On the day of discharge, June 22nd, the patient had a new bleeding, though a very minor one. Over the next week the tinnitus grew louder and he again had several minor haemorrhages. On July 7th he had a new profuse haemorrhage.

He was again admitted to the Neurosurgical Clinic and on July 10th a new left carotid angiography was performed showing that the lumen of the artery in the clamp was extremely narrow but that there was nevertheless good filling of the intracranial branches and that the aneurysm had grown (Fig. 3). On July 12th the clamp was tightened by one turn, i.e. as far as it would go. At that moment the patient said that the tinnitus ceased. No untoward reactions were observed. On July 18th a control angiography was performed and showed complete occlusion of the left internal carotid artery. There had been no recurrent haemorrhage up to Jan. 25th 1962.

Comments

The following unusual features in this case are worthy of note:

(1) There was no recent trauma in the patient's history.

(2) Carotid ligature seemed a hazardous procedure since no collateral

circulation through the anterior communicating artery could be angiographically demonstrated

(3) Though the lumen of the internal carotid artery had been reduced to about 1 mm after the first operation there was good circulation through the internal carotid artery and the aneurysm had grown

The etiology of the aneurysm must remain pure conjecture though the skull injury sustained by the patient at the age of 5 may have been its original cause This rare case therefore is a reminder that nosebleed from an intracranial aneurysm can occur even without recent trauma

Since no collateral circulation through the anterior communicating left anterior cerebral artery could be demonstrated at angiography it is probable that the circulation in the left middle cerebral artery is now largely maintained through the basilar left posterior communicating or possibly through the facial left ophthalmic artery Right carotid and vertebral angiograms would have clarified this but were thought to be somewhat risky in view of the occluded left internal carotid artery

The collateral circulation between the cerebral hemispheres cannot be estimated solely on the circulation through the anterior communicating artery I have recently seen a patient with a large supraclinoid aneurysm on the right internal carotid artery the angiograms showing very good circulation through the anterior communicating artery A Crutchfield clamp was applied to the right internal carotid artery in the neck and slowly tightened However hemiparesis developed at an estimated lumen of 4 mm and the clamp had to be opened A second attempt failed at the same estimated lumen and the clamp had to be removed

ZUSAMMENFASSUNG

Massive Nasenblutung aus der rechten Nasenhälfte bei einem 41jährigen Mann mit einem infraklinoidalen Aneurysma aus der linken A carotis interna im Sinus sphenoidalis rupturiert Angiographisch konnte man keinen Kollateralkreislauf durch die A communicans anterior feststellen Die linke A carotis interna wurde am Halse bis zu einem Lumen von ca 1 mm gedrosselt Trotzdem machte der Patient erneute Blutungen durch Eine erneute Angiographie zeigte eine gute Zirkulation durch die Stenose und eine Vergrösserung des Aneurysmas Darauf wurde die A carotis interna unterbunden Es traten keine neurologische Ausfälle und keine Blutungsrezidive auf

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ON THE USE OF HEARING AID TYPE EARPHONES IN CLINICAL AUDIOMETRY

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In a preceding article (Konig 1962) it was demonstrated that the most important factors which actually limit the range of application of the different procedures normally employed in clinical audiometry are the transcranial and transtemporal leakages The observations reported here are intended to concretize our previous theoretical considerations and to show how the use of hearing aid type earphones may enhance the accuracy of audiometric measurements In order to evidence the advantages of such earphones in a striking manner, the author gives a typical example of severe bilateral middle ear deafness where neither the air conduction curves nor the bone conduction curves could be determined correctly by means of ordinary receivers of commercially available audiometers, whereas by using hearing aid type earphones the audiometrist was able to establish a more strictly accurate audiogram In contrast to the maximum bone air gap generally observed in the different audiology centres, transtympanic transmission losses as high as 90 db were recorded at certain frequencies

INTRODUCTION

During the last decade the development of tympanoplasty as a current method of operation on the middle ear has drawn attention to the particular importance of improving the accuracy and the reliability of audiometric measurements Taking into account the various possible pathways of the sound radiated by the transducers we have already discussed in a previous work (Konig 1962) the limitations of the most popular methods used in routine audiometry It was shown that transtemporal and transcranial leakages are the factors which are chiefly responsible for the difficulties still encountered today

Although some authors (Littler Knight & Strange 1952 Hood 1957 and 1960 Palva 1958 Feldman 1961) have already pointed out how in comparison with the ordinary air conduction receivers of commercial audiometers insert earphones and perforated ear plugs made of soft rubber can be used more successfully for masking purposes (thanks to the rather high amount of the transcranial transmission losses) it would not seem that any attempts have been made to determine the air conduction hearing threshold levels of the patients ears with such new means The principal object of

the present paper was to compare and discuss the results of the audiometric measurements obtained with ordinary air conduction receivers and midget earphones of current hearing aids in the particular case of severe middle ear deafnesses

Apparatus and experimental method

All the experiments reported in this work were carried out with a Jaquet audiometer equipped with either Beyer DT 48 air conduction receivers or Siemens 16b 2–4 midget earphones The latter air conduction receiver was especially selected for our investigations because of its relatively wide frequency response and high sensitivity at the lower frequencies To minimize the transtemporal leakage and the risk of shadow hearing effects when performing audiometric measurements in certain cases of severe middle ear deafness the sound generated by the Siemens 16b 2–4 midget earphone was fed to the subject's ear through a soft transparent plastic tube provided at one end with a suitable earplug of soft plastic (so called olive as usually associated with some hearing aids) to make a tight fit in the cartilaginous auditory meatus The other end of the tube which had an inner and outer diameter of 2 and 3 mm respectively was connected to the perforated brass tip of a sort of cylindrical adapter A firm union of this Plexiglass adapter and the midget earphone was ensured by means of a circular steel spring inserted in the connector opening The above combination greatly facilitates changing the plastic tube and the olive As is shown in Fig 1 a circular headband of flexible plastic the diameter of which could be easily adapted to the different listeners head sizes permitted the midget earphones to be fastened in a very simple manner On the other hand the Beyer DT 48 receivers were mounted in flat cushions of rubber the headband also being furnished with a fairly thick rubber strip

All the threshold tests were administered in a soundproof room provided with a two way voice communication system and a Pye closed circuit television outfit The frequencies tested were presented to the subjects in the following order 1000 2000 3000 4000 6000 8000 12000 500 250 and 125 cps The intensity of the test tone was alternately increased just above or below the hearing threshold level by steps of 5 db The listeners were instructed to press and hold down the patient's signal button of the audiometer so long as the amplitude modulated test tone was perceived For a given frequency the level at which the subject could just achieve more than 50 % correct detection was considered as being the exact hearing threshold level of that listener

The output voltage of the Jaquet audiometer was adjusted so that the calibrated sound pressure of the Beyer DT 48 air conduction receiver was equal to the normal mean value of the minimum audible pressure when the attenuator (hearing loss dial) was set at zero db Seeing that unlike the Siemens 16b 2–4 earphone the electric voltages corresponding to the normal hearing threshold level for the Beyer DT 48 receiver were higher at the lower frequencies an external attenuator was placed between the output of the audio



Fig. 1. Photograph showing the Siemens 16 b 2-4 midget earphone with the transparent plastic tube and the circular headband.

meter and the midget earphone to enable the operator to decrease sufficiently the output voltage whenever subjects with nearly normal hearing were tested.

Calibration and reliability of the Siemens 16 b 2–4 midget earphone

Before starting with the experiment proper, some air conduction measurements were carried out with plastic tubes having a length of 0.5, 3, 6 and 9 cm. Plastic tubes longer than 9 cm were discarded, for an increase of the tube length tended to reduce the response at the higher frequencies in a marked manner. Moreover, since the resonance peaks can be attenuated by means of a small amount of lamb's wool or loose cotton only at the cost of a noticeable decline of the transmission characteristic of the tube in the higher frequency range, no such thread was placed inside the plastic tubes.

For a particular subject's ear and a given test tone of low frequency, the fluctuations of the air conduction curve in relation to the different tube lengths mentioned above appeared to be more or less negligible, whereas because of the presence of some resonance effects these disparities were as high as 10 db at the frequencies above 2000 cps. However, by making the tube length vary from 6 to 9 cm, the discrepancies in the air conduction curve did not exceed 5 db. In the light of the results of our measurements, it therefore seems more advantageous to use a rather long tube for the determination of the air conduction hearing threshold level, seeing that, in contrast to the

very short plastic tube, the errors due to the regulation of the tube length and the adaptation of the earplug into the auditory meatus of the subject's ear exert less influence on the air conduction curve Accordingly, all the following tests described in this paper were performed with a 6 cm long plastic tube

For the sole purpose of evaluating the efficiency and the reliability of the Siemens 16b 2 4 midget earphone the air conduction hearing threshold levels of a group of nine subjects between the ages of 20 and 29 years were determined with this midget earphone and the Beyer DT48 receiver The questioned persons were not accustomed to audiometric tests and had never complained of ear disease or difficulty in hearing

Fig 2 represents the relative fluctuations of the air conduction curve registered with the Siemens 16b 2–4 midget earphone with respect to the air conduction curve determined with the Beyer DT48 receiver The graph traced in this last figure clearly evidenced the fact that when the Siemens 16b 2–4 midget earphone is employed, the output voltage of the Jaquet audiometer must be attenuated by an amount as high as 20 db at 125 cps in order to elicit in the patient's ear a sensation of loudness equal to that produced by the Beyer DT 48 receiver Thus, the maximum intensity limit of the Jaquet audiometer supplied with the Beyer DT 48 receiver being at the 125 cps frequency as low as 65 db above the normal or zero threshold for normal hearing the use of the Siemens 16b 2–4 midget earphone permits a maximum intensity limit of 85 db to be reached for this very low test tone without producing distortion Unfortunately, we have the inverse phenomenon in the realm of frequencies above 2000 cps in fact, by providing the Jaquet audiometer with the Siemens 16b 2 4 midget earphone the maximum intensity limit is lowered Seeing that the frequency response curve of the midget earphone already showed a sharp drop of about 30 db as the frequency of the test tone was increased from 6000 to 8000 cps the data collected with pure tones higher than 6000 cps have been discarded

In order to get a faithful picture of the possible individual variabilities in threshold measurements which may be registered in routine clinical audiometry according to whether the Beyer DT48 receiver or the Siemens 16b 2–4 earphone is used the results of the measurements obtained with each ear of the different listeners have been indicated in Fig 2 by a given symbol From the pattern of these symbols one can easily deduce that at the frequencies ranging from 125 to 2000 cps inclusive the margin of errors in air conduction measurements performed with the midget earphone does not exceed ± 5 db whereas the disparities are slightly greater at the higher frequencies Undoubtedly such divergencies may be assigned to purely physical factors (fit of the Beyer DT48 receiver adaptation of the earplug into the auditory meatus resonance phenomena) as well as to higher order individual factors (degree of motivation and cooperation fatigue distraction) Nevertheless from the practical point of view the possible errors inherent in measurements made with the midget earphone are tolerable

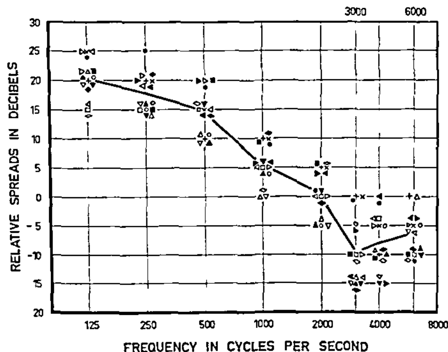


Fig. 2. Relative spreads of the air conduction curve (in db) registered with the Siemens 16b 2-4 midget earphone with respect to the air conduction curve determined with the Beyer DT48 receiver. Nine otologically normal observers between the ages of 20 and 29 years served as subjects. The results of the measurements obtained with each ear of the different listeners are denoted by a given symbol. Values above the zero line (positive) indicate that the efficiency (or sensitivity) of the Siemens 16b 2-4 midget earphone is higher than the efficiency of the Beyer DT48 receiver, while values below the zero line (negative) are associated with the inverse phenomenon. The curve traced in this figure represents the average value of the relative fluctuations as a function of frequency.

Interaural attenuation

For audiometric measurements it is important to know the amounts of the pericranial (air pathway) and transcranial (bone conduction) transmission losses of the test signal. The interaural attenuation can be determined by using various methods (Wegel & Lane 1924, Lane 1925, Békésy 1948 and 1960, Zwislocki 1953). One of the most popular and easy procedures consists in comparing the different results of the air conduction measurements carried out by patients suffering from unilateral complete deafness when the earphone is alternately applied to the two ears. For a given frequency, the interaural attenuation is then equal to the difference between the air conduction hearing threshold levels recorded from the deaf side and from the normal side.

Fig. 3 shows the interaural transmission losses for the Beyer DT 48 air conduction receiver and the Siemens 16b 2-4 midget earphone (provided with a hearing aid type insert of soft plastic) as a function of frequency

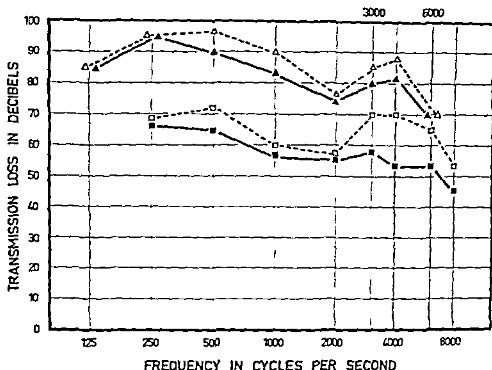


FIG. 3 Interaural transmission losses for the Beyer DT48 air-conduction receiver and the Siemens 16b 2 4 midget earphone (provided with a hearing aid type plastic tube insert) as a function of frequency Three young monaurally completely deaf observers served as subjects Each point represents the average of determinations made with three different observers ■——■ Interaural attenuation for the Beyer DT 48 receiver when the auditory canal of the untested ear is open □- - - -□ Interaural attenuation for the Beyer DT48 receiver, when the auditory canal of the untested ear is firmly closed with the finger ▲——▲ Interaural attenuation for the Siemens 16b 2 4 midget earphone when the auditory canal of the untested ear is open △- - - -△ Interaural attenuation for the Siemens 16b 2-4 midget earphone when the auditory canal of the untested ear is firmly closed with the finger

Three young monaurally deaf observers served as subjects The dashed curves of Fig 3 indicate that the interaural transmission losses have been determined by closing firmly the auditory canal of the normal ear with the finger while the results of the measurements obtained with open meatus are represented by the continuous curves Although pressing with the finger on the tragus exerts in the realm of frequencies above 2000 cps only a negligible influence on the bone conduction hearing threshold level of a normal ear, one may register with such a manoeuvre a gain in bone hearing of 5 to 15 db at the lower frequencies (Bekesy, 1939 and 1960) Furthermore, according to our own data collected with some subjects with normal hearing it appears that closure of the auditory canal of the ear under examination produces for that ear an elevation of the air conduction hearing threshold level which amounts to about 20 25 and 30 35 db at the lower and higher frequencies, respectively Since for a given frequency and a particular earphone, the amount of the difference between the interaural transmission losses recorded

with the closed and open meatus is positive (or equal to zero) and lower than 20 db, it can safely be concluded that on the basis of the above mentioned observations the two dashed curves of Fig. 3 give the transcranial transmission losses for the Beyer DT48 receiver and the Siemens 16b 2–4 midget earphone respectively (the reduction of the transcranial attenuation due to the occlusion effects of the untested ear being included); moreover, in the regions where for a given receiver the dashed curve lies at least 5 db higher than the continuous curve, this latter curve undoubtedly represents the pericranial transmission losses (the auditory canal of the untested ear being open).

In a general manner it may be admitted that the transcranial transmission losses for the Beyer DT48 air conduction receiver varies between 50 and 70 db, whereas by leading the sound into the ear through the hearing aid type insert of soft plastic the transcranial transmission losses may increase to figures as high as 70–95 db. These observations seem to be in good agreement with the generally accepted opinion that the amount of the transcranial attenuation increases as the area of the head exposed to the air-bone sound waves decreases (Békésy 1948 and 1960, Littler, Knight & Strange 1952, Zwislocki 1953, Hood 1957 and 1960, Palva 1958). Furthermore, since the vibrations imparted to the skull at the air–bone interface bounding the receiver are transmitted to the cochlea of the untested ear without being damped in a marked manner, it should be noted that the above mentioned figures for the transcranial transmission losses are also more or less valid for the corresponding transtemporal transmission losses.

Audiometric tests in the case of severe middle ear lesions

The audiograms of Figs. 4 and 5 are two typical examples of severe middle ear deafness which clearly evidence the fact that our previous theoretical considerations and conclusions based on a detailed analysis of some hypothetical cases (König 1962) have not just a purely academic interest but are actually of real practical importance.

Fig. 4 represents the audiogram of a 37 year old patient who was operated on four years ago because of right sided *otitis media chronica*. At that time an endaural conservative radical operation was undertaken on this latter ear. Unfortunately, the healing of the radical cavity was later disturbed by a tubal discharge. Seeing that on applying to the right ear the masking noise (narrow band) generated by the Beyer DT48 receiver the audiometrist was unable to determine the bone conduction hearing threshold level of the left ear (vibrator on the forehead) without producing cross masking effects (bone air gap of the right ear being nearly equal to the transcranial transmission losses), a second audiogram was then taken with the Siemens 16b 2–4 midget earphone. By means of this midget earphone it was possible to estimate the bone conduction hearing threshold level for the left ear with a certain margin of safety. Moreover, as may be seen in Fig. 4, the air conduc-

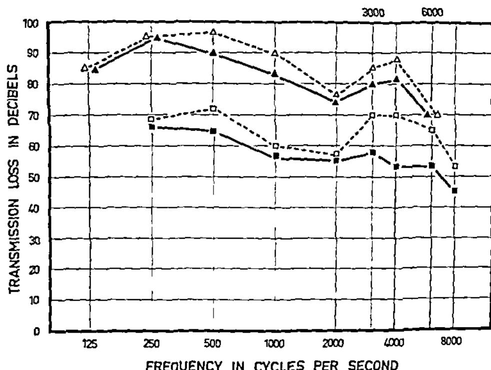


Fig. 3. Interaural transmission losses for the Beyer DT48 air conduction receiver and the Siemens 16b 2-4 midget earphone (provided with a hearing aid type plastic tube insert) as a function of frequency. Three young monaurally completely deaf observers served as subjects. Each point represents the average of determinations made with three different observers. ■——■ Interaural attenuation for the Beyer DT 48 receiver when the auditory canal of the untested ear is open. □- - -□ Interaural attenuation for the Beyer DT48 receiver, when the auditory canal of the untested ear is firmly closed with the finger. ▲——▲ Interaural attenuation for the Siemens 16b 2-4 midget earphone when the auditory canal of the untested ear is open. △- - -△ Interaural attenuation for the Siemens 16b 2-4 midget earphone, when the auditory canal of the untested ear is firmly closed with the finger.

Three young monaurally deaf observers served as subjects. The dashed curves of Fig. 3 indicate that the interaural transmission losses have been determined by closing firmly the auditory canal of the normal ear with the finger, while the results of the measurements obtained with open meatus are represented by the continuous curves. Although pressing with the finger on the tragus exerts in the realm of frequencies above 2000 cps only a negligible influence on the bone conduction hearing threshold level of a normal ear, one may register with such a manoeuvre a gain in bone hearing of 5 to 15 db at the lower frequencies (Békésy, 1939 and 1960). Furthermore, according to our own data collected with some subjects with normal hearing, it appears that closure of the auditory canal of the ear under examination produces for that ear an elevation of the air conduction hearing threshold level which amounts to about 20–25 and 30–35 db at the lower and higher frequencies respectively. Since, for a given frequency and a particular earphone, the amount of the difference between the interaural transmission losses recorded

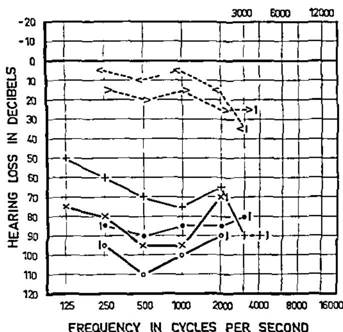


Fig 5 Audiograms of K E 65 years m

by using an ordinary air conduction receiver of commercially available audiometers in cases of bilateral middle ear deafness as described above the accuracy of the results obtained with the new procedures recommended by Rainville (1955) Lightfoot (1960) and Jerger & Tillman (1960) is also limited by the transcranial and transtemporal leakages

DISCUSSION AND CONCLUSIONS

Certainly in view of the growing interest in and wide use of the air and bone conduction tests for the evaluation of hearing impairments and for the estimation of improvement effected by surgical treatment the difficulties still encountered today in threshold measurements of hearing acuity in patients suffering from severe middle ear lesions cannot be overlooked A cursory examination of the literature on clinical audiometry gives the impression that the possible errors caused by transtemporal leakages in air conduction testing have not been considered with all due caution

In this study it was shown that in the cases of middle ear deafness where for a given test tone the bone air gap recorded with a particular air conduc tion receiver is nearly equal to the transcranial transmission losses, the otologist who interprets the audiograms may underestimate the amount of the true transtympanic transmission losses According to the results of our measurements it is however possible to diminish the occurrence of such errors in routine audiometry by having recourse to hearing aid type earphones

Unfortunately, seeing that in respect of the ordinary air conduction receivers usually supplied with commercially available audiometers the sensitivity of the midget earphones is relatively low at the frequencies above 6000 cps, a general application of the hearing aid type earphones in clinical audiometry appears to be premature. Nevertheless, in particular cases where by employing the ordinary receivers the air conduction curve or the bone conduction curve of the ear under examination cannot be ascertained with a sufficient margin of safety, the use of hearing aid type earphones should be especially recommended. Finally, it is interesting to note that because of its light weight the midget earphone may be very helpful when testing children or patients suffering from head injuries.

RÉSUMÉ

Dans un travail récent (König 1962) on a démontré à l'aide de quelques exemples hypothétiques que le champ d'application des procédés couramment employés en audiométrie tonale est d'autant plus limité que les pertes de transmission transcrâniale et transtemporale sont basses. En s'appuyant sur des observations cliniques on essaye, dans cet article, de concrétiser les considérations théoriques antécédentes et de montrer dans quelle mesure l'utilisation des écouteurs à conduction aérienne des appareils de prothèse auditive permet de hausser la précision des mesures audiométriques. Afin de mettre en évidence les avantages de ce genre d'écouteur d'une façon frappante, l'auteur donne un exemple typique de surdité bilatérale d'oreille moyenne où il a été impossible d'évaluer correctement les courbes des seuils aérien et osseux au moyen d'écouteurs ordinaires, alors qu'en employant de petits écouteurs l'audiométriste a pu relever l'audiogramme de ce malade d'une manière plus rigoureuse. Grâce à ce dernier procédé, on a été ainsi à même de déceler dans le domaine de certaines fréquences des pertes de transmission transtympanique de 90 db.

ZUSAMMENFASSUNG

In einer vorangehenden Arbeit (König 1962) wurde an Hand einiger hypothetischer Beispiele bewiesen, dass der Anwendungsbereich der gebräuchlichsten Methoden der Reintonaudiometrie umso begrenzter ist, je niedriger die Überleitungsverluste durch den Schädel und das Schläfenbein sind.

In der vorliegenden neuen Publikation wird versucht, mit Hilfe klinischer Beobachtungen unsere früheren theoretischen Betrachtungen zu konkretisieren und zu zeigen, wie die Genauigkeit der audiometrischen Messungen durch Anwendung der Luftleitungshörer von Hörgeräten gesteigert werden kann. Um die Vorteile dieser Art von Luftleitungshörern überzeugend darzulegen, gibt der Autor ein typisches Beispiel von bilateraler Mittelohrschwerhörigkeit, wo es mittels gewöhnlicher Luftleitungshörer unmöglich war, die Luft- und Knochenleitungskurven richtig zu bestimmen. Der Gebrauch von Miniaturhörern erlaubte jedoch dem Audiometristen, ein genaueres Reintonaudiogramm aufzunehmen. Dank diesem letzteren Untersuchungsverfahren ist es gelungen, bei gewissen Frequenzen Differenzen von 90 db zwischen der Luft- und der Knochenleitungskurve festzustellen.

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ON THE PATHOGENESIS OF LARYNGEAL INJURIES FOLLOWING PROLONGED INTUBATION

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Extensive ulcerations appear in the larynx after about 20 hr intubation. The pathogenesis of these ulcerations is discussed on a basis of histological and roentgenological investigations. The authors have found that (*a*) the ulcerations are pressure sores, (*b*) the period of intubation should be as short as possible and should not exceed 24 hr, (*c*) if possible intubated patients should not lie with their heads bending backwards, (*d*) in case of prolonged intubation, tubes other than of the Magill type might be used.

Many different opinions have been expressed concerning the period of time a laryngeal tube can remain in the larynx and the importance of this in relation to the genesis of laryngeal injuries. Many authors have refrained from discussing the problem at all—probably on account of their investigations having been limited to complications arising from intubation in general anesthesia. In such cases the tube never remains in the larynx for more than 8 to 10 hr, except on special occasions. Dwyer, Kronenberg & Saklad (1949), however, have discussed the importance of the length of intubation and have claimed that ulcerations do not occur before 6 hr intubation. On the other hand these authors state that traumatized congested areas have appeared within 2–4 hr after intubation. Crispell & Hampton (1950) consider that the risk of larynxedema increases with the duration of intubation.

In the treatment of unconscious patients (barbiturate poisoning, cerebral injury, etc.) there have been considerably longer periods of intubation. Most handbooks (Moeschlin 1959, for example) claim that the tube can remain for 48 hr. A number of authors (i.e. Clemmesen & Nilsson 1961) have claimed that the tube can remain for as much as 96 hr on condition that the tube is changed at short intervals and that the larynx is inspected each time (tracheotomy is carried out if there is any indication of damage). A careful survey of the literature relating to laryngeal injury following intubation was made by Bergström earlier this year.

Pathological-anatomical Investigations

In order to derive as true a picture as possible of the type and extent of injury following prolonged intubation we have carefully investigated the

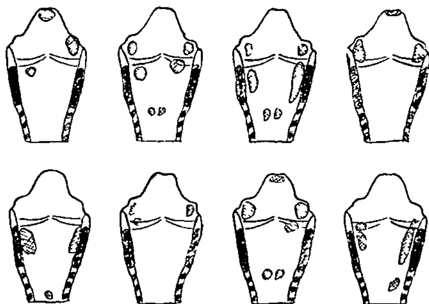


Fig 1 Schematic pictures of the larynx sectioned from behind in eight cases which have died after 16½–96 hr intubation The black areas represent the cricoid cartilage and the upper tracheal cartilages The lined areas are the ulcerations in the mucous membrane

upper respiratory tracts of a number of patients who died after having been intubated from 16½ up to 96 hr Seven of these cases have previously been thoroughly reported by Bergstrom (1962) This work should be referred to for a detailed description of the clinical background and the pathological-anatomical findings Since then a few cases of the same type have been observed

In all the cases investigated we have observed multiple ulcerations of the mucous membrane in the larynx These ulcerations are sometimes covered by muco purulent membranes and are thus first discovered through microscopic investigation Histologically the ulcerations have the appearance of more or less profound necroses in the mucous membrane with pronounced acute inflammatory reaction in the vicinity In all cases which have been intubated for more than 30 hr the process was so profound that the inflammation had even penetrated to the underlying cartilage In extreme cases the cartilage can be denuded at the base of an ulceration It should be pointed out that the ulcerations are not always connected with upper respiratory infection Furthermore in some cases there is extensive ulceration without any noteworthy inflammatory changes in the larynx in general

Fig 1 shows the localization and extent of the ulcerations in eight cases (cases 1–7 are those reported by Bergstrom) It can be seen from the picture

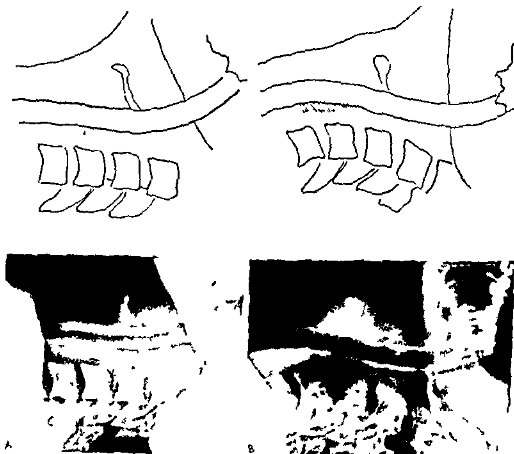


Fig. 2. Roentgenograms with corresponding schematic pictures in lateral projection showing a Magill tube in position. *A*, with the head bent forwards. *B*, with the head bent backwards. The shadowed area between the lower part of the tube and the cervical vertebral column is the cricoid shield.

that the ulcerations are most often localized to the arytenoid region, the dorsal parts of the vocal cords and the dorso-lateral parts of the subglottic space. Thus five cases show ulceration in the arytenoid region, five in the central or dorsal parts of the vocal cords and six in the subglottic space. In three cases there are also small ulcerations in the epiglottis and in five cases small ulcerations in the tracheal mucous membrane, as a rule localized to the ventral wall of the trachea. The ulcerations are principally oval or elongated with the major extension in the long axis of the larynx.

Radiological Investigation

The localization of the ulcerations to the dorso-lateral parts of the larynx concurs with Matzker's investigations of the position of the tube in the larynx. It is nevertheless surprising, and by no means in agreement with the information given in the literature, that the ulcerations should so often be

localized to the subglottic space In order to investigate this the position and form of the tube in intubated patients has been examined roentgenologically

A number of patients who have been intubated with a Magill tube were examined roentgenologically and the results in all cases were alike When the head is bent forward the tube retains its normal form to a great extent i e a slight curve even though the lower end of the tube straightens out When the head is bent backwards however the tube assumes an S form (Fig 2) The tube is supported here by the dorsal shield of the cricoid cartilage which in its turn is supported from behind by the lordosis of the cervical vertebral column The farther back the head is bent the more the cricoid cartilage push against the tube

When the tube is deformed in this way on account of the tube s elasticity the point presses on the ventral wall of the trachea This emerges from the roentgenograms although there is a certain difficulty involved in making a free *picture of the trachea from the shoulder section in a lateral projection* The changes however can easily be observed in model tests which have also been shown by Dwyer Kronenberg & Saklad

DISCUSSION

These investigations have thus shown extensive ulceration of the larynx following intubation These pressure sores occur after a relatively short period (16 hr) Necroses of the laryngeal cartilages is observed in all cases where intubation exceeds 30 hr

The ulcerations seem to be localized principally to the dorso lateral region of the larynx In several cases the largest ulcerations are observed in the subglottic space Intubated patients usually lie with the head bent backwards As a result of this the dorsal shield of the cricoid cartilage which is supported by the lordosis of the cervical vertebral column is pushed up from behind against the tube which is thus distorted Post mortem examination of the larynx reveals that the dorsal part on the same level as the vocal cord is relatively pliable On the other hand in the subglottic space the wall consists of the rigid cricoid shield which at least in older patients is often calcified/ossified These conditions would thus seem to be the explanation for the ulcerations in the subglottic space

The investigations have also revealed that when the dorsal shield is pushed forward the tube assumes an S form The point of the tube then presses against the ventral wall of the trachea This seems to explain the ulcerations in the ventral wall of the trachea in five of the eight cases referred to in Fig 1

Laryngeal injuries thus appear as pressure sores resulting from the static pressure of the tube Changing the tube as proposed *inter alia* by Nilsson (1951) does not alter this but simply introduces the risk of increased traumatism Therefore as stated previously by Bergstrom the period of intubation should be kept as short as possible and should not exceed 24 hr

In some cases extended periods of intubation are necessary In order to avoid unnecessary laryngeal injury the unconscious, intubated patient should, if possible, be placed with the head bending forwards In the event of prolonged intubation it should also be considered whether another type of tube than, for example, the Magill might be used A tube of the Rusch type is more suitable here and should result in less injury.

ZUSAMMENFASSUNG

Nach einer Intubationsdauer von ungefahr 20 Stunden treten ausgebreitete Ulzerationen im Larynx auf Die Pathogenese dieser Geschwure wird mit Berucksichtigung durchgefuhrter histologischer und röntgenologischer Untersuchungen disku tiert Die Verfasser finden, dass a) die Ulzerationen Decubitalgeschwure sind, b) die Intubationsdauer so kurz wie moglich gehalten werden soll und nicht 24 Stunden übersteigen soll, c) der intubierte Patient, wenn moglich nicht mit nach hinten ge beugten Haupt liegen soll, d) man bei langerer Intubationsdauer daran denken soll, andere Tubustypen als den von Magill zu verwenden

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CONGENITAL CYSTS AND FISTULAE OF THE NECK

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After an anatomical and clinical review of congenital lateral and medial cysts and fistulae the operative methods are discussed The material consists of 42 cases 25 of them being lateral and 17 medial After operative treatment there were no recurrences in lateral cysts and fistulae while in medial abnormalities the recurrence occurred in six cases In complete lateral fistulae the operative method presented of v Hacker is recommended In thyroglossal cysts and fistulae the middle portion of the hyoid bone should always be removed

Congenital cysts and fistulae of the neck lateral and medial lie on the borderline between surgery and otolaryngology and the pertinent articles published before the Second World War were invariably included in surgical journals During the last two decades however a swing of opinion towards otolaryngology has been observed the present article is concerned mainly with methods of treatment and with the existing possibilities of preventing recurrences

Lateral cysts and fistulae of the neck

Etiology Several theories have been advanced on the origin of lateral cysts and fistulae of the neck and there are still two diverging opinions Ascherson stated as early as 1832 that they are branchiogenic in origin Later Bailey (1923) and Nylander (1927) among other investigators concurred in this opinion Wenglowski (1913) attributed these cysts and fistulae to failure of the thymopharyngeal duct to become obliterated However cysts and fistulae due to this cause are rare (Proctor 1955) one such case has been published by Rudberg (1954)

The current opinion (Malcolm & Benson 1940) is that the etiological factors in cervical cysts and fistulae are

(1) Epithelial remnants of the branchial system
(2) Incomplete closure of the visceral groove
(3) Rupture of the cleft membrane
(4) Persisting cervical sinus

Anatomy Bailey (1923) divided the branchial cysts into four groups according to site

(1) Superficial cysts situated at the anterior border of the sternomastoid muscle immediately below the fascia

(2) The cysts adjoining the internal jugular vein and adherent to it in varying extent This is the most common form

(3) Those located between the external and internal carotid arteries and extending to the proximity of the lateral pharyngeal wall

(4) Those situated in the lateral pharyngeal wall medially to the carotic artery

The fistulae are classified into three groups the internal the external and the complete The external fistulae are the most common according to Neel & Pemberton (1945) these accounted for 50 per cent the complete for 40 per cent and the internal for 10 per cent of all cases

In the case of fistulae and cysts originating from the second third and fourth pharyngeal pouch or groove the anatomical relations with the cervical nerves and blood vessels are very constant provided that there are no vascular anomalies Thus the external opening of the fistula is always in front of the anterior margin of the sternomastoid muscle Naturally a fistula can develop behind this line if cysts are incised

The anatomy of a fistula arising from the second pharyngeal pouch or groove is described fully by Proctor to which the reader is referred A tract arising from the third pharyngeal pouch or groove passes from the anterior margin of the sternomastoid muscle into the deeper portions below the common carotic artery anterior to the vagus and opens in the lateral pharyngeal wall at the level of the hyoid bone

Diagnosis Most commonly a cyst presents as a painless mass usually below the mandibular angle The mass grows slowly but may also increase in size rapidly after injuries and during infection The size varies and fluctuation is often recognizable The cysts are mobile if inflammation has not caused adhesions to the surrounding tissues Diagnosis is usually easy though in a few cases it can only be confirmed by histopathological study

In most of the cases about 90 per cent the wall is lined with stratified squamous epithelium in 10 per cent with columnar epithelium or by both these types Infection may destroy the epithelium in a few cases *Subepithelial* lymphocytic infiltration is a typical feature The following conditions should be kept in mind in the differential diagnosis tuberculous lymph nodes lymphangiomas neoplasms dermoid cysts thyroid cysts carotic body tumours and medial cysts of the neck which may be situated lateral to the midline

A typical lateral fistula of the neck is often visible even at birth although the opening which is usually at the anterior border of the sternomastoid muscle near the sternoclavicular joint may be missed because of its small size As a rule it is not recognized until the fistula becomes infected or mucus secretion sets in The fistulous tract can often be palpated as a firm cord under the skin If the fistula is complete its external opening moves upward



Fig 1 Fistulography of an incomplete lateral fistula



Fig 2 Fistulography of a complete lateral fistula

with deglutition Palpation or probing of the fistula may produce signs of vagus stimulation (Carp 1926) The histopathological picture is similar to that of cysts The fistulous tract can be demonstrated by injecting contrast medium into the duct In addition to the pathway of the fistula this will show whether the fistula is complete or not (Figs 1 and 2) Knowledge of this is of particular importance in the case of incomplete fistulae extending close to the lateral pharyngeal wall Differential diagnosis from tuberculous fistula is required rarely

Treatment The only proper treatment is radical removal Sclerosing substances have been used earlier (e g Beck) They have the advantage that no scar results but the disadvantage that an intense inflammatory process develops with necrosis of the surrounding vital tissues In the presence of inflammation it is good to wait until it subsides and perform needle aspiration if required

The incision is performed parallel to the skin folds over the cyst the accessory nerve and if operating at a higher level the lower branch of the facial nerve should be identified at the beginning of the operation so as not to cause damage to them The cyst sac with all its extensions is freed bluntly from the surrounding tissues special care is required when dealing with cysts of the third group Rupture of the wall often renders work difficult If some epithelium remains this will result in recurrence

Removal of a fistula should preferably be performed under general anesthesia since local anesthesia is associated with difficulties if the fistula extends



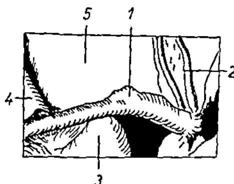


Fig. 3. A view from the mouth showing the invaginated fistular duct. 1 = invaginated outdrawn duct. 2 = right tonsil. 3 = uvula. 4 = left posterior palatine arch. 5 = posterior pharyngeal wall.

into the deeper portions or opens into the pharynx. It is easier to follow the fistulous tract and its extensions if methylene blue is injected into the opening. Proctor (1955) recommends washing away of surplus colouring matter with saline to avoid staining of the operation area in case of rupture of the duct. During the operation it is no longer worth while injecting colouring matter. Christopher (1930) injected liquid paraffin into the fistulous duct; as it solidifies, the tract can more easily be dissected free. A fine plastic bougie serves the same purpose well (Voegeli 1961).

The best visual exposure is afforded by an incision made along the anterior margin of the sternomastoid muscle, but a better cosmetic result is obtained with a transverse incision parallel to the skin folds, which includes excision of the external opening of the fistula. If the opening is situated very low, then one or two horizontal auxiliary incisions are made higher up. With the aid of these incisions it is possible to dissect the tract up to the pharynx.

If the fistula is incomplete, it is of utmost importance that it is removed radically. In dissecting the terminal part it is helpful if the assistant places his finger in the fossa Rosenmuller and pushes the tissues laterally. If the fistula is complete, it can be cut through and ligated near the pharyngeal mucosa. The possibility is then present that the end portion of the fistula continues to drain into the pharynx and it may even be infected. To avoid this von Hacker uses invagination of the fistula with the aid of a bougie passed from the external opening into the pharynx (Fig. 3).

Material. The present series is shown in Table 1. It consists of 20 cases of lateral cysts and five lateral fistulae of the neck treated surgically at the Department of Otolaryngology, University Central Hospital, Turku, in the period 1952–61. Cysts of the second group (Bailey's classification) were the most common (12 cases). Two patients had been operated on earlier in other hospitals but the cysts recurred in a few months. The incision was made parallel to the skin folds, except in one case in which it followed the *anterior margin* of the sternomastoid muscle.

Three of the fistulae were complete and two external. One of these latter

TABLE 1 *Lateral cysts and fistulae*

	Cysts		Fistulae		Total	
Male	7	20	3	5	10	25
Female	13		2		15	
Right side	9	20	4	5	13	25
Left side	11		1		12	
Bailey I group	3	20			20	25
II group	12					
III group	5					
Complete			3	5	5	
Incomplete			2			

ended in a tonsil, which was removed at the same time In three cases the fistula was invaginated as recommended by Hacker Auxiliary incisions had to be made to widen the visual exposure in three cases

In neither of the groups was there any recurrence

The epithelial lining in all cases of fistulae consisted of stratified squamous epithelium, and the same applies to 14 cysts, in three of which there was in addition columnar epithelium Columnar epithelium alone occurred in no single case In six cysts the epithelium had been destroyed by infection

Medial cysts and fistulae of the neck

Etiology During the fourth week of intrauterine life the anlage of the thyroid gland develops in the pharyngeal portion of the primitive intestine, ventral to it In the adult this position corresponds to the foramen caecum In the course of development the primitive thyroid structure descends to its normal position in the lower part of the neck forming a tubule (thyroglossal duct), which normally is later obliterated (thyroglossal tract) In some cases the duct fails to become obliterated with the result that a fistula or cyst is formed, as pointed out by His (1886) In most cases (Sistrunk, 1928) a persisting patent duct drains through the foramen caecum and remains unnoticed When the duct owing for instance to infection becomes blocked close to the base of the tongue any fluid secreted from it no longer drains but follows the thyroglossal tract causing a cyst to develop somewhere between the base of the tongue and the thyroid gland most frequently below the hyoid bone For this reason medial cysts and fistulae of the neck though congenital, may appear at any age they are most common in youth however A cyst may rupture spontaneously if it is incised a fistula also develops

The cysts are classified according to site into those located above at the level of, and below the hyoid bone The fistulae like the lateral ones are of three kinds external internal and complete A fistula passes either through or behind the hyoid bone more rarely anterior to it up to the base of the tongue

The fistulae occupy a midline position but cysts may be situated also laterally however they are always connected with the hyoid bone by a tract or duct In the area between the base of the tongue and the hyoid bone there are often extensions of the duct

Diagnosis is generally easy A soft painless fluctuating mass is situated in the midline or close to it and moves upward with deglutition Occasionally a cord connecting it with the hyoid bone can be palpated or will be revealed at operation if not earlier It is more difficult to diagnose a cyst above the hyoid bone which—if infected—can be confused with an abscess of the floor of the mouth or base of the tongue Conditions to be remembered from the differential diagnostic point of view are dermoid cysts and ranula

The wall of a cyst or fistula is lined by squamous epithelium or by columnar epithelium which later usually occurs in combination with the former Subepithelially there is a typical layer of lymphocytes Sometimes the cyst includes thyroid tissue

Treatment is surgical Extirpation must be radical so that it includes removal of the middle portion of the hyoid bone for a distance of about 1 cm This must be done also in those cases in which the tract seems to terminate in the hyoid bone since as a rule it continues towards the base of the tongue above the hyoid bone Schlange was the first to call attention to this fact as early as 1893 In 1920 Sistrunk states that the tract passing from the antero superior margin of the hyoid bone to the foramen caecum should always be removed as it may contain epithelial islets which cause recurrence Occasionally it is difficult to identify this tract and then it is advisable to remove a tissue cylinder about 6 8 cm in diameter and passing in the midline from the middle of the hyoid bone backward and upward at an angle of 45 degrees this tissue will include also the thyroglossal tract Dissection of the terminal portion is facilitated if the assistant places a finger on the base of the tongue and pushes it outward Special attention should be given to the extensions of a fistula or cyst their dissection is made easier by injection of methylene blue into the channel The open communication created into the pharynx is meticulously closed a thin drain is placed in the wound and it is *closed in layers*

Material The present series consists of 17 developmental anomalies of the thyroglossal tract (nine fistulae and eight cysts) The cases are listed in Table 2 The majority of the patients were under 20 years of age the oldest 52 years Most frequently the cysts and external opening were situated below the hyoid bone

Recurrences were remarkably frequent This is due to the fact that in only six cases was the middle portion of the hyoid bone removed at the first operation In none of these six instances did a recurrence appear However there was a recurrence in six out of the 11 cases in which the middle portion of the hyoid bone was not removed indeed in five of these there were two recurrences Definitive cure was not obtained until after resection of the

TABLE 2 *Medial cysts and fistulae*

	Cysts		Fistulae		Total	
Male	5	8	5	9	10	17
Female	3		4		7	
Above hyoid bone	1	8	1	9	2	17
At hyoid bone	1		2		3	
Below hyoid bone	6		6		12	
No recurrences	4	8	7	9	11	17
One recurrence	—		1		1	
Two recurrences	4		1		5	

middle part of the hyoid bone and complete removal of the cyst or fistula above it

An illustrative case is a boy of 11 years subjected twice to removal of a fistula extending to the hyoid bone, without resection of the middle part of the bone When the part of the hyoid bone was removed at the third operation, a cyst, the size of a cherry, was disclosed behind it In another case, a young man of 19, a medial fistula had been removed earlier at another hospital The fistula, however, had recurred When eating, clear fluid escaped from it Operation showed that the fistulous tract passed through the hyoid bone and divided, near the base of the tongue, into three branches, which were removed

The cyst or fistula was lined in five cases by squamous epithelium, in two by columnar epithelium, and in five by both these types In one case of fistula there was epithelium of intermediate type, in addition to squamous and columnar epithelium In five cases no histological specimen was available

DISCUSSION

The disadvantage caused by congenital cysts and fistulae of the neck is usually cosmetic and hygienic When they become infected more serious damage may arise The chances of malignant transformation are slight, though Ward & Hendrick (1950) reported malignancy in seven of 70 branchiogenic anomalies In other studies the incidence of branchiogenic carcinoma is much lower, for example Neel & Pemberton's (1945) 319 cases included none of carcinoma

When performing operations for congenital anomalies of the neck their origin and anatomy must be known The main principle must be to remove any secreting epithelium, otherwise recurrences will ensue This applies in particular to medial cysts and fistulae, in which the hyoid bone appears a 'convenient' end point of the operation Even though the whole of the tract may not extend beyond the hyoid bone, failure to remove the middle part of the bone leads so frequently to recurrences that it must be considered a

technical error to omit such a resection. Thus in the series of Ward *et al.* (1949) a recurrence appeared in 25 per cent of the patients operated on without extirpating the middle portion of the hyoid bone but in only 6 per cent of those 34 cases in which this procedure was undertaken. Pemberton & Stalker (1940) reported on 261 cases with only four recurrences (1.5 per cent). In all of their cases the middle part of the hyoid bone was removed and additionally, in almost every case the tract connecting the hyoid bone and the base of the tongue, regardless of whether a fistula was visible or not. In Mathisen's 22 cases there were no recurrences. The high incidence of recurrences in the present series (6/17) indicates clearly the essential importance of removal of the middle part of the hyoid bone and of any remnants of the thyroglossal tract.

Lateral cysts and fistulae, especially those extending to the pharynx or close to it through the carotic bifurcation, are technically more difficult to remove than the medial anomalies. It is probably due to this fact that surgeons seem to have dealt with the former cases with particular care, and so recurrences in published reports have been infrequent. In Neel & Pemberton's study (1945) the result was good in 309 cases (95 per cent). Lahey's (1941) and Ward's report included no recurrences. Preparation for operation should include fistulography, which discloses the pathway and length of the fistula and shows possible extensions. If a fistula extends up to the pharynx, this can also be demonstrated by means of stain injected into the duct.

Cosmetically it is of advantage to make the incision parallel to the skin folds. If the skin round the external opening is inflamed, a sufficiently extensive excision is made. In the present series 11 out of 42 patients replied to a follow-up inquiry that the scar was clearly visible. Six of these patients had had wound infection. The risk of wound infection is reduced if a cyst or fistula is not operated upon while inflammation is present. As the operation requires simultaneous manipulation in the pharynx and on the neck, sterile conditions should be maintained as far as possible.

Medial cysts and fistulae of the neck in most cases appear before the age of 20. Lateral fistulae are usually recognizable at birth, but lateral cysts do not appear until after the age of 20 years. Of the medial anomalies in this series 82 per cent occurred in patients under 20 years, of the lateral cysts only 24 per cent. These figures in Nylander's case material (1927) were 79 per cent and 26 per cent respectively. It is difficult to know the reason for this. If inflammation plays a part in the manifestation of cysts or fistulae, as Sistrunk assumed in the case of medial anomalies, it may be thought that the medial formations become infected more easily and therefore earlier because of their site and structure. It remains an open question how great a proportion of the branchiogenic and thyroglossal tract anomalies do not become manifest at all.

ZUSAMMENFASSUNG

Nach der anatomischen und klinischen Übersicht auf die kongenitalen lateralen und medialen Halsfisteln und Zysten werden die operativen Methoden diskutiert.

Das Material enthalt 42 Falle, von denen 25 sind lateral und 17 medial Es gab keinen Rezidiv nach der operativen Behandlung der lateralen Halsfisteln und zysten, wahrend in den medialen Missbildungen der Ruckfall in sechs Patienten erschien Es wird empfohlen, die Methode von v Hacker fur die Entfernung der kompletten lateralen Halsfisteln anzuwenden In Fallen mit Zysten und Fisteln von ductus thyreoglossus muss der mittlere Teil des Zungenbeins immer entfernt werden

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THE SENSATION OF COLD IN RELATION TO THE INCIDENCE OF THE COMMON COLD IN MALE AND FEMALE STUDENTS

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A questionnaire concerning some symptoms related to cold was sent to 200 male and 200 female students. A greater proportion of the females than of the males had a tendency to feel cold and to have cold hands and feet. Nasal discharge or obstruction on returning to room temperature after exposure to cold was also more common in the female students. These results were compared with those of previously reported experiments, in which it was found that women usually had a lower skin temperature than men and that the decrease in the temperatures of the finger, foot and nasal mucosa on exposure to cold air was generally greater in women.

The male students had an average of 3.0 common colds per year, as compared with 3.2 in the females. In the subjects with more than three common colds per year the tendency to cold hands was slightly more common than in those with three or fewer common colds. The personal impression that cooling might provoke a common cold was slightly more frequent among subjects with more than three than in those with three or fewer common colds per year.

INTRODUCTION

In a study of the temperature regulation of human subjects, Hardy & Du Bois (1940) found that the skin temperature of women was lower than that of men. The investigation was performed at room temperature on naked subjects (2 men and 7 women). This result was confirmed by Drettner (1961) in a material of 20 men and 20 women, all lightly and uniformly dressed. Significant sex differences in the skin temperatures were found on the forehead and lower leg, and there was a similar tendency, but not statistically significant, on the chest, finger and foot. The lowest skin temperature values were found in women who had a history of frequent common colds, and the highest ones in men with fewer than three common colds per year.

During exposure to cold the decrease in skin temperature of the hand appears to be more pronounced and of longer duration in women than in men. Hustin (1935) found that during immersion of one hand in cold water the consensual decrease in the temperature of the other hand was usually greater in women than in men. According to Burckhardt (1950) the spontaneous rewarming of the skin of the hand after cold hand baths was more often delayed in fertile women than in men. Heidelmann & Schmidt (1957) ar

rived at the same result with experiments on a series of hospital patients with various diseases Drettner (1961) showed that the decrease in finger temperature after the subjects had entered a cold climate chamber was significantly greater in females than in males and a similar tendency was found for the foot temperature In experiments where the feet or back were cooled no such sex difference in the finger temperature decrease was found Nor did the decrease in the skin temperature of the forehead chest or lower leg show any obvious differences between male and female subjects during different cooling experiments Subjects with histories of frequent common colds showed on exposure to cold a decrease of the finger temperature of about the same degree as subjects with few common colds

In this last mentioned study it was also found that the temperature of the nasal mucosa dropped more in the female subjects than in the male in those cooling experiments where the back or the inspiratory air was cooled as well as after entrance into a cold climate chamber

The subjects in this study were questioned as to whether they often had cold hands or feet or a tendency to general coldness These symptoms appeared to be more common in women than in men and more common in subjects with *frequent than in those with few common colds*

Further, 15 of the 20 subjects with a history of four or more common colds per year stated that they considered them to be provoked by some form of exposure to cold while none of the 20 subjects with three or fewer common colds per year had this impression

The aim of the present investigation is to study the distribution of these symptoms mentioned above and also some other symptoms related to cold in a larger material and to attempt to ascertain whether there are any differences in the occurrence of these symptoms in men and women or in subjects with many or few common colds per year

MATERIAL

During the autumn of 1961 a questionnaire was sent to 200 male and 200 female students born between 1936 and 1940 These were chosen in proportion to the number of students in the thirteen student clubs (nations) in Uppsala The names of the students to whom letters were sent were taken from the bottom of the lists in the different clubs and the material thus principally consisted of students who had only been at the University of Uppsala for a short time As each club comprises students from a distinct district of Sweden those chosen came from all parts of the country except the most southern regions

The questions sent were as follows

1 How many common colds do you have per year on an average?
2 Do you tend to feel cold easily?
3 Do you often have cold hands?
4 Do you often have cold feet?

5 Do you have nasal discharge or nasal obstruction when *you return to* room temperature after being out in the cold?
6 Do you have the impression that you catch a cold after *some form of* cooling e g cooling of the feet?
7 Do you have allergic nasal discomforts e g hay fever?
8 Do you take an active interest in outdoor sports? Great moderate little or none?
9 When did you last perform military service? (for male students only)
10 Any additional information

RESULTS

Answers to the questionnaire were received from 173 of the 200 male students (86 5 %) and from 167 of the 200 female students (83 5 %) The reply figure in the whole material was thus 85 %

The annual frequency of common colds in the male and female students in this material is shown in Fig 1 As seen in this figure the female students showed a tendency to a slightly greater number of common colds per year *than the males* The mean numbers of common colds per year in the male and *female* students were 3 0 and 3 2 respectively The difference was not statistically significant The median values which may provide more information regarding the number of common colds in the majority of students were 2 3 and 2 6 in the male and female students respectively

In order to ascertain whether the results obtained from the answers were different in those who had few and those who had many common colds

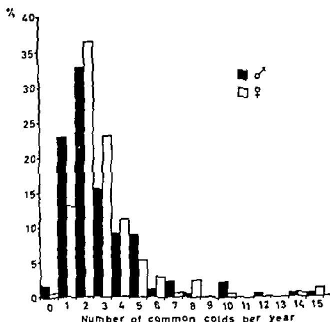


Fig 1 The percentage distribution of the number of common colds per year in the male and female students

TABLE 1 *The percentage distribution of positive answers to the questions in relation to sex and to the frequency of common colds per year*

	♂			♀			♂ + ♀		
	Common colds yr			Common colds yr			Common colds yr		
	<3	>3	Total	<3	>3	Total	≤3	>3	Total
Tendency to feel cold	23 5	22 2	23 1	60 9	75 0	65 3	41 8	48 1	43 8
Often cold hands	16 8	33 3	22 0	56 5	67 3	59 9	36 3	50 0	40 6
Often cold feet	26 9	42 6	31 8	59 1	65 4	61 1	42 7	53 8	46 2
Nasal discharge or obstruction after exposure to cold	21 9	29 6	24 3	36 5	41 2	38 9	29 1	36 8	31 5
Personal impression that cooling may provoke a common cold	18 5	29 6	22 0	24 4	36 5	28 1	21 4	33 0	25 0
Allergic nasal discomforts	8 4	11 1	9 3	10 4	11 5	10 8	9 4	11 3	10 0
Great or moderate interest in out door sports	47 9	42 6	46 2	30 4	30 8	30 5	39 3	36 8	38 5
Military service during the previous six months	22 7	27 8	24 3				11 5	14 2	12 4

per year, the answers were grouped into the following two parts, both for the male and the female students (*a*) subjects with three or fewer common colds per year, and (*b*) those with more than three common colds per year The latter groups comprised 54 male and 52 female students i e 31 2 % of the male and 31 1 % of the female students had more than three common colds per year As these figures were essentially the same in the male and female students it was possible to study the results of the questions both in relation to sex and to the frequency of common colds when the borderline of three common colds per year was chosen

The results obtained from the answers to the questions, grouped according to the principles given above are shown in Table 1 The figures are given in per cent The material was treated statistically The notations *, **, and *** are used to indicate the significance levels of $0.01 < P < 0.05$, $0.001 < P < 0.01$, and $0.001 > P$, respectively

With the exception of the question regarding interest in sport, the female students gave a higher percentage of positive answers than the males In the subjects with three or fewer common colds per year, significant sex differences were found for the questions about the tendency to feel cold (***), the tendency to have cold hands (***) and feet (***) and about the discomforts from nasal discharge or obstruction upon returning to room temperature after exposure to cold (*) The male students with three or fewer common colds took a more active interest in outdoor sports than the corresponding females (*)

Among the subjects with more than three common colds per year the

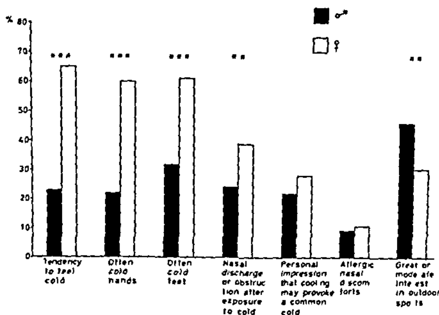


Fig. 2. The percentage distribution of positive answers to the questions in the male and female subjects. When the differences in positive answers are significant, the degree of significance is denoted by asterisks above the columns.

female students gave a significantly greater number of positive answers to the questions about the tendency to feel cold (***) and to have cold hands (***) and cold feet (*).

For these three last mentioned questions the differences in positive answers were highly significant (***) when all the male and all the female students were compared. A significant difference (**) between these two groups was also found concerning nasal discomforts on sudden changes of the surrounding temperature (question 5), the male students having a higher frequency of positive answers than the female. The sex difference regarding interest in sport was also significant (**): the male students took a more active interest. The frequencies of positive answers in the male and female students are illustrated diagrammatically in Fig. 2.

On comparison between subjects with few and those with several common colds per year, only few significant differences were found. The male subjects with more than three common colds per year gave a higher percentage of positive answers regarding the tendency to have cold hands and feet than the males with three or fewer common colds per year; these differences were significant (*). No other statistically significant differences were found between these two groups. In the female subjects no significant differences in the number of positive answers were found between those with more or fewer than three common colds per year.

In Fig. 3 the frequency of positive answers for all subjects with three or fewer common colds per year are compared diagrammatically with the

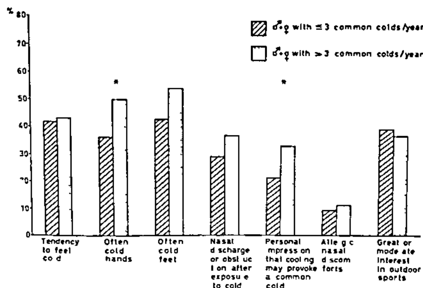


FIG 3 The percentage distribution of positive answers to the questions in the subjects with three or fewer common colds per year and in the subjects with more than three common colds per year When the differences in positive answers are significant the degree of significance is denoted by asterisks above the columns

corresponding frequency for all subjects with more than three common colds The last mentioned group generally had a higher percentage of positive answers, for the questions concerning the tendency to have cold hands this difference was significant ( ) The difference was also significant (*) regarding the personal impressions of whether cooling may or may not provoke a common cold The subjects with the higher frequency of common colds had this impression more often (33 %) than those with fewer common colds (21 %) It is worthy of observation that the degree of active interest in outdoor sports was practically the same in these two groups Nor was there in these two groups any obvious difference in the relative incidence of male students who had performed military service during the previous six months

DISCUSSION

It is evident from the results that the female subjects had a greater tendency to feel cold and to have cold hands and feet than the male This difference was highly significant As pointed out previously, the skin temperature of naked or lightly clothed subjects is usually lower in women than in men under ordinary room conditions (Hardy & Du Bois 1940 Drettner, 1961) During exposure to cold the decrease in skin temperature of the finger and foot is generally greater in females than in males (Drettner 1961) Since cold receptors are confined to the skin the lower skin temperature in women than in men during room conditions and the greater decrease in the skin temperature of the hands and feet during exposure to cold may explain the

fact shown in this investigation that women tend to feel cold and to have cold hands and feet more often than men.

It may seem difficult to reconcile this sex difference in reaction to cold with the well known fact that women sustain long periods in cold water, e.g. when swimming the English Channel, better than men. These observations may not be mutually incompatible, however. Since women usually have a thicker layer of subcutaneous fat than men, they may be better able to maintain the temperature of the interior of the body during prolonged exposure to cold. On the other hand, the better the thermal insulating properties of a tissue, the greater the tendency to a steeper temperature gradient when differences in temperature exist between its two sides. This may, according to Hardy & Du Bois (1940), possibly explain the lower skin temperature in women than in men under conditions where the ambient temperature is lower than that of the body. Sex differences in the skin temperature of the hand and foot may hardly be explained in this way, however.

Another conceivable explanation for the sex difference in skin temperature is that the vasoconstrictive tendency of the skin on exposure to cold might be more pronounced in women than in men. The fact that the decrease in finger temperature on exposure to cold is greater in women than in men (Drettner 1961), that a cooled hand remains cold for a longer period in women (Burckhardt 1950, Heidelmann & Schmidt 1957) and that the consensual decrease of the skin temperature of a hand on cooling of the other hand is also greater in women (Hustin 1935) may all support the hypothesis of a sex difference in the vasoconstrictive tendency of the skin on cooling, at least in the hand. In a group of female subjects who entered a cold climate chamber, the decrease in the finger temperature was usually greatest in those experiments which were performed during the third week of the menstrual cycle (Drettner 1961). The present study provides no information on whether the tendency to feel cold or to have cold hands or feet is more common during certain periods of the menstrual cycle than in others.

In this material the tendency to nasal obstruction or nasal discharge after returning from a cold climate to room temperature was more common in the female subjects than in the male. In this connection it may be worthy of mention that the decrease in the temperature of the nasal mucosa during exposure to cold air was greater in a group of female than in a group of male subjects (Drettner 1961), but whether these observations are connected is impossible to judge.

Since all the subjects were active students with similar indoor occupation, the sex differences in the discomfort caused by cold could not be explained by differences in occupation between the male and female students. The male subjects in this material, however, took a more active interest in outdoor sports than the female. The males might thus have become more accustomed to cold during sports and during military service than the females, which might partly explain the fact that the male subjects had fewer discomforts associated with cold than the female.

The female subjects in this material had on an average 3 2 common colds per year and the male subjects 3 0 Several authors (Lidwell & Sommerville 1951 Andrewes 1953 Badger *et al* 1953 Buck 1956) have previously reported that women acquire common colds more frequently than men The transmission of infections to women from their children might explain the sex difference in the common cold frequency in the material of some of these authors In the present material however practically all of the subjects were unmarried

The personal impression that cooling might provoke a common cold was more frequent in the subjects with more than three common colds per year than in those with three or fewer common colds It is impossible to judge whether this impression has any real basis The only scientifically proved occasion when cooling may increase the susceptibility to a common cold is in women during the middle third of the menstrual cycle (Dowling *et al* 1957) The decrease in nasal temperature during cooling of the inspiratory air is usually more pronounced at about that stage of the cycle than during the other stages (Drettner 1961) In the present material no statistically significant sex difference was found in the impressions regarding the susceptibility to common cold after cooling

ZUSAMMENFASSUNG

200 Studenten und 200 Studentinnen wurde ein Fragebogen zugesandt worin Erkundigungen nach einigen mit Kalte verbundenen Symptomen eingezogen wurden Die Neigung zu frieren kalte Hande und Fusse zu haben war bei den Frauen im Verhaltnis haufiger als bei den Mannern Nasenfluss und Nasenverstopfung bei der Ruckkehr zu der Zimmertemperatur nach einem Aufenthalt in der Kalte war ebenfalls haufiger bei den Damen Diese Ergebnisse wurden mit denen fruher berichteten Versuche verglichen bei denen gefunden wurde dass die Hauttemperatur bei Frauen gewohnlich niedriger was als bei Mannern und dass die Temperaturabnahme in Finger Fuss und Nasenschleimhauten beim Kontakt mit kalter Luft im allgemeinen bei Frauen ausgepragter war

Die Studenten hatten im Durchschnitt 3 0 gewohnliche Erkaltungen im Jahr verglichen mit 3 2 bei den Studentinnen Bei den Personen mit mehr als drei Erkaltungen im Jahr war die Neigung zu kalten Handen etwas haufiger als bei den Personen mit drei oder weniger Die personliche Auffassung dass Abkuhlung eine Erkaltung hervorrufen kann war bei den Personen mit mehr als drei Erkaltungen im Jahr etwas haufiger als bei denen mit drei oder weniger

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THE 4000 DIP: ANATOMIC CONSIDERATIONS[1]

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In a number of sectional series of temporal bones of malformed fetuses and newborn, the enchondral layer of the cochlear capsule was found to perforate, in a broad stream, the periosteal layer and to meet beyond the latter the so called cartilage (chondral) bar. This third interruption of the capsular layers—the first and second being the internal acoustic meatus and the cochlear aqueduct—is located in the basal cochlear turn corresponding to the 4000 dip of the audiometric curve. Lack of shielding by the periosteal layer, combined with the disturbance of the enchondral layer caused by the abrupt change of direction, may create here an area of diminished protection for the underlying membranous parts.

This interpretation, based on observations in the osseous capsule, is offered as a counterpart to the explanatory attempts regarding the 4000 dip which consider happenings in the membranous portions exclusively.

Investigation of this "enchondral outflow" in normals of different ages is desirable.

For physiological reasons which still are uncertain, pure or complex sounds too intense or too prolonged, of whatever frequency, leave a lesion predominantly in the region of the audiometric curve corresponding to the area of the basilar membrane connected with perception of the 4000 cycle, i.e. in man the middle of the basal turn (Portmann & Portmann 1961). This is the region usually first damaged in any kind of cochlear deafness, whatever the cause (Watkyn-Thomas 1953).

Attempts to explain this phenomenon are numerous. Practically all are restricted to analysis of occurrences in the soft parts, the membranous content of the cochlea. The purpose of this presentation is to describe a particularity found *not in the membranous parts but in the bony capsule of the cochlea* corresponding to the critical region. In this section of the basal turn an outflow of the enchondral layer interrupts the periosteal cover. Situated somewhat higher in the cochlear wall than the orifice of the cochlear aqueduct, it is separated from the latter by a distinct layer of bone, to be described in detail.

MATERIAL AND METHODS

The observations were made in sectional series of human temporal bones originating from the fetal or early perinatal period. A short condensation of the relevant histories follows.

[1] Supported by Grant No. [illegible] [illegible] American Otological Society.



FIG 1 11 hen atoxyl n–eo in vertical plane Boundaries of the participation of the enchondral layer in building the wall of the bottom of the internal acoustic meatus To all figures. *CB* cartilage bar *E* enchondral layer *EO* enchondral outflow *P* periosteal layer interrupted.

CASE 1 (Fig 1) Born after an uneventful pregnancy this male died at 3½ months of age Malnutrition was present with multiple anomalies including several in the cephalic region type Treacher Collins.

CASE 2 (Figs 2 and 3) Surgical interruption at the 21st gestational week was indicated by diabetes of the mother The female fetus showed mesenchymal filling in the middle ear leaving in the inner ear the cochlear duct already free Ossification was in intensive progress in the periosteal layer with the marrow spaces of the enchondral layer still wide (reported in detail Kelemen 1960)

CASE 3 (Fig 4) The premature boy was born at the 31st week of gestation (reported in detail Kelemen 1955)

CASE 4 (Fig 5) The premature girl was born at the 34th week of gestation Multiple malformations including cephalic were listed among them microcephaly and widely separated sutures and bilaterally persistent stapedial arteries (reported in detail Kelemen 1958)

CASE 5 (Fig 6) The girl born in breech presentation died during delivery Malformations of the stapes and the inner ear were noted

CASE 6 (Fig) Born at term in breech presentation died at delivery Sex not given Normal temporal bones were found with mesenchymal resorption consistent with the age (discussed by Niccoli Vallesi 1958)

FIG 2 ×11 hematoxylin-eosin horizontal plane Broad outflow of the enchondral layer crossing the entire thickness of the periosteal layer and ending at the cartilage bar

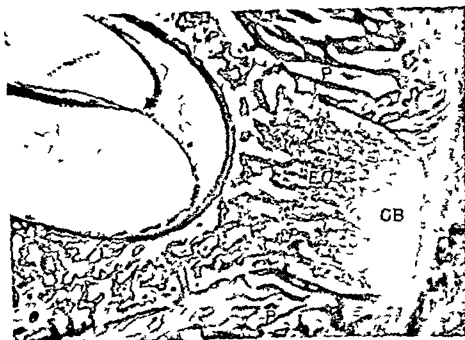


Fig 3 Same series as Fig 2

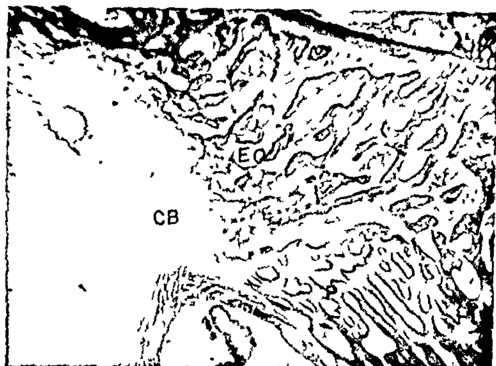


Fig. 4. ×30 hematoxylin eosin horizontal plane. Outflow interrupting the periosteal layer and abutting in the cartilage bar

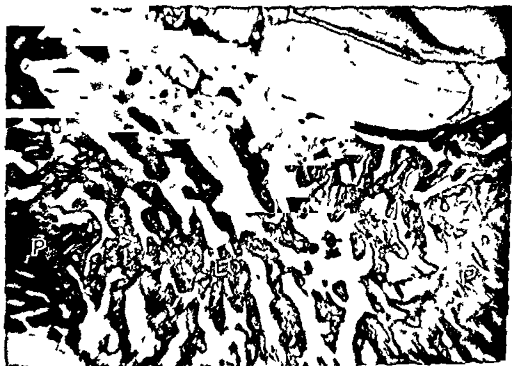


Fig. 5. ×30 Heidenhain Mallory horizontal plane. Stream of central outflow with endosteal layer intact

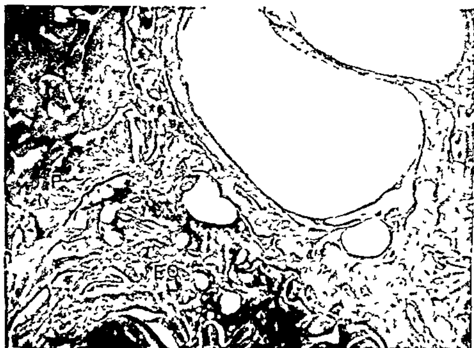


Fig. 6. ×30. hematoxylin–eosin, horizontal plane

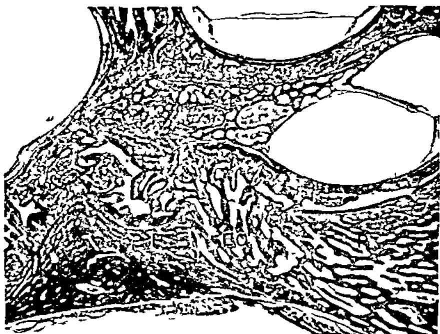


Fig. 7. ×14. Gomori impregnation, horizontal plane



Fig 8 13 hematoxylin-eosin horizontal plane Enchondral stream abutting in cartilage bar

Case 7 (Fig 8) The 2 days old white girl presented multiple malformations among these in the cephalic region microcephaly choanal atresia hemangioma of the nose The hearing organ was in adequate evolutionary stage with almost complete resorption of the mesenchyme

Case 8 (Fig 9) Delivery of the boy who died after 3 days was difficult due to face presentation and a large encephalocele Hypoplasia of the cerebellum was found in anomalous midbrain shallow posterior fossa upward deviation of nerve roots fracture of the skull not affecting the temporal bone Suppurative otitis media was present

Case 9 (Figs 10 and 12) The girl with erythroblastosis died when three days old (reported in detail Kelemen 1956)

Case 10 (Fig 11) Born after an uneventful pregnancy at term the white boy died at nine weeks of age Several congenital defects were noted among these in the cephalic region defect of the occipital bone hydranencephaly microcephaly

The specimens were fixed in Bouin or formalin decalcified in five per cent nitric acid embedded in celloidin The sectional series were stained with hematoxylin eosin Heidenhain Mallory impregnation according to Gomori and in some cases with special stains Unstained mounted sections were left for observation in polarized light

Release of this material by the departments of pathology of the Boston Lying in Hospital and the Children s Medical Center both of the Harvard Medical School is gratefully acknowledged

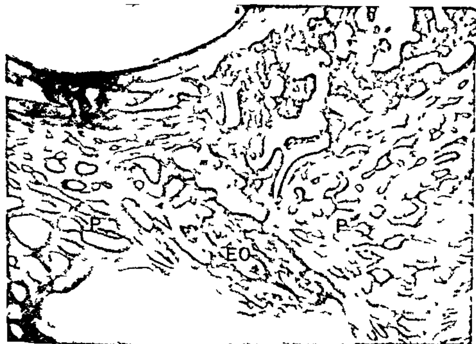


Fig 9 ×30 hematoxylin eosin vertical series Enchondral stream ending in cartilage bar

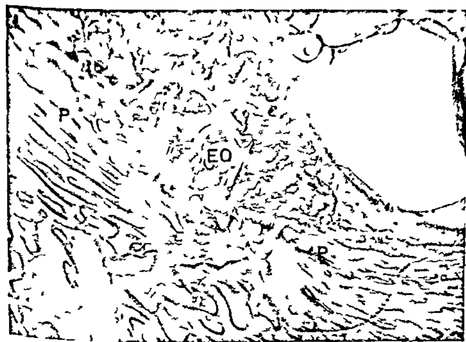


Fig 1 ×31 hematoxylin eosin horizontal plane Enchondral stream breaking through the periosteal layers but not reaching the cartilage bar (the latter seen in the left lower corner)



Fig 11 12 hematoxylin e sin vertical plane



F 12 12 hemat xyl n e sin vertical plane Cochlear a queduct with vein in separate canal I nd steal l ning t end 1 wn sm x th1 t form a funnel un ler1 ne t 1 y enel n iral 1 o e

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OBSERVATIONS

The walls of the fundus of the inner acoustic meatus are formed by the enchondral and the periosteal layers while the endosteal is perforated to become the cribriform lamina But enchondral and periosteal layers do not participate in building the entire length of the canal While the periosteal bone proceeds with parallel lamellae for the entire length and reaches the cortical of the temporal bone at the subdural orifice of the meatus the enchondral layer disappears much higher It surrounds the upper half of the fundus and ends with a sharp line about at the level of the crista transversa (Fig 1)

Another formation interrupting the main course of the layers of the osseous capsule is the cochlear aqueduct Here contrary to the inner meatus it is the endosteal layer which bends to form the infundibular orifice of the canal arranging its lamellae in a longitudinal wall (Fig 12) Here too the enchondral layer follows to a certain distance but leaves the perforation of the cortical portions of the temporal to the canal forming endosteal layer (Wolff Bellucci & Gaston 1957 Fig 148) According to the description of Waltner (1945) the cochlear aqueduct in adults is surrounded by a wedge like mass of periosteal bone along its entire length—the wedge naturally having to traverse the enchondral layer—while in the six month old fetus the vein of the aqueduct acquires a separate bony canal consisting of periosteal bone

The enchondral bone shows a particular disposition near the inner meatus and the aqueduct as shown in Figs 2 to 11 In the basal coil somewhat higher than the orifice of the aqueduct and with the endosteal layer remaining intact the enchondral bone in a wide stream cuts its way *across* the lamellae of the periosteal bone The lamellae of the latter can be covered against the enchondral leak by a sort of sealing terminal lamina as seen e g in Figs 4 and 7 or can remain cut straight through as seen in Figs 4 8 and 10

There is no connection with the wall of the aqueduct on the other hand the flow can go over into the enchondral mass surrounding the upper half of the fundus of the internal acoustic meatus in which case it is peculiar that the source of the enchondral wall of the fundus should originate from so high up so far away from the inner meatus The funnel of the cochlear orifice of the aqueduct can be formed by a very thin endost cutting straight through the enchondral layer (Kelemen 1934 Fig 1) Incidentally Fig 1 shows in the enchondral mass a small cartilaginous nucleus near the egress of the facial nerve

The enchondral stream may end by meeting a large cartilaginous mass (Figs 2–4 8 10) This cartilage bar or chondral bar ossifies much later than other portions of the otic capsule remaining as cartilage according to Bast & Anson (1949) as late as the 20th embryonic week In Case 3 (Fig 4) it was present in the 31st gestational week in Case 8 (Fig 9) and Case 9 (Fig 10) in the third postnatal day Possibly this was in connection with other

abnormal features exhibited in these instances. Bast and Anson postulated further study regarding the relation of this late ossification to certain pathological processes, as in the fenestral region. At the boundary of the outpouring enchondral column and the cartilaginous mass, ossification of the latter was in full progress.

Among the two main interruptions of the course of layers of the cochlear capsule, the wall of the aqueduct is formed by the endosteal and the periosteal layer and between the two by the enchondral layer for a varying distance between the cochlear and the subarachnoideal orifice; the walls of the meatus are formed by the periosteal layer and, in the region of the fundus, the enchondral layer, with the endosteal lining left behind to form the cribriform lamina. In the region of the enchondral outflow, as described here, the periosteal cover is lacking and the cochlear wall is formed by the endosteal and the enchondral layers.

This section gains a particular significance by being located at the level about eight to ten millimeters from the basal end of the basilar membrane damaged so predominantly in cases of acoustic trauma and represented in the audimetric curve as the depression called the 4000–5000 or c_5 dip. This dip—*corresponding in man to the middle of the basal turn—was the object of* a great number of investigations, as summarized from the historical and the critical viewpoint by Ruedi & Furrer (1946). But the explanatory hypotheses took into consideration only changes in the membranous cochlea, leaving apart the osseous shell. Certain relations between the osseous cranial base and the function of the membranous inner ear were explored by Gyergyay & Gyergyay (1948) and Šercer & Krmpotić (1960).

Ruedi & Furrer (1946) mentioned cranial injuries without bone fracture where the damaging acoustic factor reaches the cochlea by bone conduction (Fig. 16 with the production of a typical c_5 dip). The area as described here represents a region where the periosteal shield is lacking, thus leaving a region of diminished resistance for an impact of the nature mentioned in the above publication. They mentioned two factors pointing in the direction of less resistance within the area in question: the middle of the basal turn is a predilectional region for autolytic phenomena in the organ of Corti; also, quoting von Békésy, they emphasize that at this point the basilar membrane is much exposed to damage by pairs of eddies rotating here in opposite directions.

The tract as described here would mark a region broad enough to let fall into its boundaries the frequencies between 3500 and 5000. To broaden this dip in the audiometric curve an increase of the load is generally needed.

There seem to be no data known to distinguish the discussed area in its relation to the cochlear content from any other sector of the globe-like capsule. It would be of importance to have some orientation about the adherence of the soft parts to the bony walls and to gain some idea regarding a possible interplay between them.

Neubert (1950) examined the system by which the basilar membrane is

anchored At its external termination the spiral ligament is molded with a broad basis into the concavity of the external cochlear wall The membranous parts end in the periosteum with a fibrous layer markedly thicker in the region of the base of the spiral lamina Neubert was able to demonstrate with his preparatory technique that the relation between the bone and the external aspect of the spiral ligament is not very intimate to a certain extent displacement here is possible He showed a diagram (Fig 8) with a narrowing down of the vestibular and tympanic scalae about in the center of the basal turn resulting in a veritable isthmus and this pointed to the possibility that under abnormal loads disadvantageous effects may appear as this contracted area forms a region of increased vulnerability corresponding to the segment of 5000 c p s

von Békésy (1960) found the greatest difficulty in opening a cochlear canal because of its lining—a tough thin membrane that adheres only loosely to the bone

The study of the outflow as described here would have to be followed regarding its potentialities The phenomenon is easily seen e g in the Figs 43 61 138 of the atlas of Wolff Bellucci and Eggston The question—one of many offering themselves—of the late ossification of the chondral bar should be studied on normals as our material was selective and contained only cases with malformations It may be added that as in the pictures of Wolff Bellucci and Eggston —as well as in our series—the horizontal *and* the vertical plane offered opportunities for these observations Further investigations in this region (in the sense of the neglected dimension to quote the expression of Sercer 1961) are desirable

ZUSAMMENFASSUNG

In einer Anzahl von Felsenbein Schnittserien fotalen und neugeborenen mit Missbildungen, konnte man beobachten dass die enchondrale Schicht der Schneckenkapsel die periostale Schicht durchbrach um jenseits des letzteren die sogenannte knorpelige Leiste zu erreichen Diese dritte Unterbrechung der Kapselschichten nebst des inneren Gehorganges und der Schneckenwasserleitung — findet sich in der basalen Windung entsprechend der Stelle der 4000 Senke der Audiometrie In diesem Gebiet fehlt der Schutz der periostalen Schicht die enchondrale ist in ihrem Aufbau gestort so mag hier eine Verminderung der Widerstandsfähigkeit entstehen Diese Voraussetzung beruht auf Beobachtungen in der knöchernen Kapsel und wird denjenigen gegenubergestellt welche die Entstehung der 4000 Senke ausschliesslich in die membranösen Teile verlegen Es ist erwünscht die Natur dieses enchondralen Ausflusses in normalen Felsenbeinen verschiedenen Alters klarzulegen

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EXFOLIATIVE CYTOLOGY IN OTOLARYNGOLOGY USING SULFHYDRYL ACTIVITY, ACRIDINE ORANGE AND MORPHOLOGIC STAINING PROCEDURES[1]

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Exfoliative cytology has been tested in a selected series of 50 cases of malignant tumours in the ENT area Wiping of the tumour surface with a cotton wool swab has proved the most suitable method of collecting samples To demonstrate cell morphology the May-Grunwald Giemsa and Papanicolaou staining procedures have been used and found equally reliable The sulfhydryl (SH) activity was shown to be higher in malignant cells, which therefore can be recognized more easily and quickly than with morphological methods With fluorescence microscopy using acridine orange certain malignant cells are visualized by a bright red fluorescence The two cytochemical methods, and especially the SH technique, have proved a valuable complement to conventional staining procedures but the final diagnosis must still depend on morphological criteria Our investigation has clearly demonstrated that cytodiagnosis can be of material value for a rapid diagnosis and is a suitable tool in oto rhino laryngology

INTRODUCTION

Exfoliative cytology is the study of superficial cells and collections of cells which are continually shed off (exfoliated) from mucous membranes and the linings of the body cavities and in particular from malignant tumours in such sites The method is particularly suited to those regions of the body which are difficult to inspect and where the opportunities for biopsy are limited Cytological diagnosis has therefore been concentrated above all on the discovery of malignant tumours in the uterus and lungs In oto rhino laryngology there are several areas which are difficult to examine and where a malignant tumour may remain hidden for too long and remain undiagnosed The epipharynx and the paranasal sinuses are examples of this Enhanced possibilities of early diagnosis would be of great prognostic value The intention in our work has been to study the value of cytological diagnosis in malignant tumours in ENT practice and to compare different technical methods for the collecting of samples and staining of smears

[1] The work has been carried out with financial support from the Swedish Cancer Society

PREVIOUS INVESTIGATIONS

It is of historical interest that tumour cells in sputum from a case of cancer in the throat were described over 100 years ago (Beale, 1860) During the last 15 years the method has become of great practical value and a number of studies concerning clinical cytology in otolaryngology are available, in which both normal and atypical cell pictures in different diseases have been described Larger general surveys have been published by Friedmann (1951), Liebersat (1951), Probst & Pfaltz (1953), Papanicolaou (1954), Bryan & Bryan (1959), and Koss (1961) Several detailed studies of smaller and more limited areas include nasopharynx (Morrison, Hopp & Wu 1949, Hopp, 1958), oral cavity (Hopp, 1958, Sandler, 1961), maxillary sinus (Fitz-Hugh, Moon & Lupton, 1950), oesophagus (Messelt, 1952, Pfaltz & Probst, 1953 Johnson *et al*, 1955, Gephart & Graham, 1959, Brandborg *et al*, 1961), middle ear (House, 1949, Ojala & Palva, 1955) Bronchial cytology has not been included in this work since it has not been considered as belonging to true otolaryngology The value of cytological diagnosis in lung cancer has been documented by numerous authors (Wandall, 1944, Farber *et al*, 1950, Hjelt, 1953, Foot, 1955, Umiker, 1960, Wiman, 1959, 1960, 1962, Nasiell, 1962)

Another branch of clinical cytology is aspiration biopsy (fine needle puncture), the diagnostic value of which has been well documented by Soderstrom, 1958, Franzen, 1958, and others The method is well suited for rapid diagnosis of malignant tumours in otolaryngology (Stahle, 1960, 1962)

MATERIAL AND COLLECTION OF SAMPLES

The study includes about 50 selected patients with tumours in the nose, paranasal sinuses, nasopharynx, oral cavity, pharynx, hypopharynx, oesophagus, larynx and external auditory meatus and middle ear In all cases the diagnosis has been verified by histopathological examination

The technique of collecting samples has varied on account of the different anatomy in the areas which have been examined Five methods have shown themselves suitable after testing

1 Direct wiping of the tumour surface with a cotton wool swab of varying length This technique is most suitable for visible lesions and has in practically all such cases given sufficient and representative material Collection of samples from nasopharynx is best performed with Yankauer's speculum which after surface anaesthesia of the mucous membrane, is inserted under the soft palate and allows direct inspection of the posterior and lateral walls Other alternatives for collecting samples from this region are (*a*) with a bent cotton wool covered probe inserted via the mouth under simultaneous posterior rhinoscopy, and (*b*) with a straight probe direct via the nose after shrinking of the mucous membrane and under simultaneous anterior rhinoscopy Blind wiping of the mucous membrane of the nose and nasopharynx can sometimes also give representative material

2 Superficial scraping with a fine spoon or curette This method gives in comparison with that described above a preparation richer in cells but the cell density may be too large for diagnosis It is suitable for leukoplakia in the oral cavity, hypopharynx and larynx

3 Aspiration of secretions from the suspect area at times following saline irrigation It is essential that the secretions are collected in a container placed as near the sucker s orifice as possible This reduces the risk of losing cells by adhesion to the walls of the suction tubes The secretions must be centrifuged before preparation This method has been used predominantly in cancer of the oesophagus but in some cases in the nose also

4 Sputum specimens after clearing the throat and then expectorating Yellow or grey white preferably bloodstained masses are especially suitable for cytological examination

5 Blowing the nose directly on to a glass dish with simultaneous compression of the nostril on the healthy side Secretions can be teased out on the same glass or divided up on to several dishes This procedure for obtaining samples which has not been described previously in the literature has given preparations rich in cells in cases of cancer of the nose and paranasal sinuses It is assumed however that obliteration of the nasal cavity is not complete and some passage of air is allowed

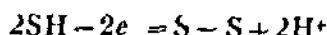
STAINING METHODS

In this study both conventional morphological and modern cytochemical staining methods have been used together The intention has been to compare their usefulness in this section of clinical cytology and estimate their reliability The latest developments in cancer research have thereby been used to try out new methods in clinical cytology

Sulfhydryl activity in exfoliated normal and malignant cells

Since the discovery of pilothione by de Rey Pailhade (1888) extensive studies have been made to clarify the biochemistry of the sulfhydryl groups in the human organism SH groups occur either bound to proteins or free in the form of glutathione cysteine or methionine (Pearse 1960) The proteins are built up of groups of polypeptide chains which in their turn are composed of amino acids bound to each other by alpha amino and alpha carboxyl groups To the side chains are linked amino carboxyl and SH groups which together with the amino acid of the polypeptids form a pattern characteristic for each protein molecule By the nature of the linkage and its localisation in the molecule the possibilities of the SH group to react with other compounds are determined On account of this Barron (1951) differentiates freely reacting protein bound SH groups which react readily with weak oxidizing agents and slowly reacting SH groups which demand more powerful oxidizing agents Finally there are SH groups which are so well protected that denaturing with accompanying depolymerisation of the protein molecule is necessary before they can react with other materials

Free SH groups in the form of glutathione form with ascorbic acid an oxidation reduction system of the type



$$2SH - 2e \rightleftharpoons S - S + 2H^+$$

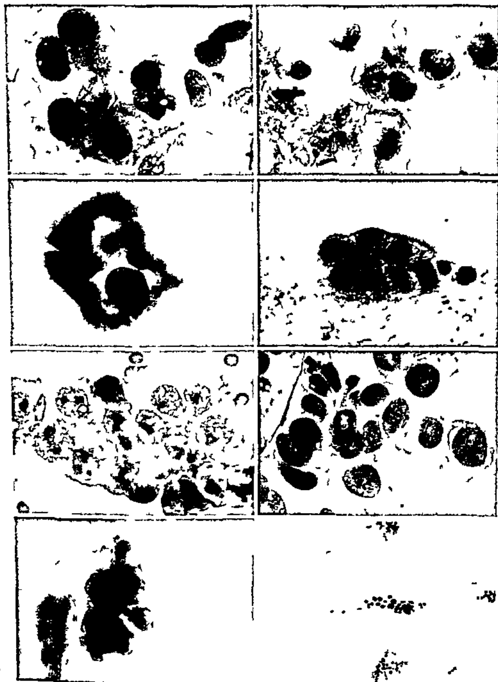
The SH groups are thus of the greatest importance in cell respiration and cell division Free and protein bound SH groups are also necessary for a great many enzymic actions and are therefore indispensable for division and growth of cells Other processes important to life which demand the presence of SH groups are hormone synthesis and activity capillary permeability electrolyte balance antibody production muscle contraction insulin production keratin formation and others

The basis of protein synthesis is of the greatest interest in all problems concerning the division and growth of cells under both normal and pathological conditions It has therefore been reasonable to study sulfhydryl bonds and protein synthesis in malignant tumours Several authors have shown both experimentally and clinically an *increased concentration of SH groups in malignant tumors* (Voegtlin & Thompson 1926 Binet & Magrou 1931 Bahr, 1957 Moberger & Bahr 1958 amongst others)

The most specific method of showing protein bound sulfhydryl groups histochemically is described by Barrnett & Seligman 1952 who also provided satisfactory proof of its specificity A disulphide bond oxidizes the protein bound SH groups and a coloured azo compound is then formed with a naphthol bond In Bahr's modification (1957) 2 2 dihydroxy 6 6 dinaphthyl disulphide (DDD) reacts in excess at pH 8 5 with active SH groups in fixed tissue proteins with the formation of a colourless substance It can be converted to an intensely coloured azo compound by combination with diazotized 4 amino 3 6 dimethoxy 4 nitroazobenzene (Fast Black Salt or Echtschwarzsalz K) The colourless oxidation product is insoluble in both water and ether alcohol so that both the excess of DDD and other byproducts from the reaction can be washed from the tissue with organic solvents *The result of the reaction is a deep blue colour of varying intensity where the intensity is directly proportional to the number of accessible SH groups (Bahr 1957 Bahr & Moberger 1958)*

After clinical and experimental testing on normal and malignant tissue Moberger & Bahr (1958) showed an increased concentration in the actively infiltrating parts of the tumour and in peripheral portions of solid cancer cords The superficial SH rich malignant cells are however very readily exfoliated and can with cytological methods be shown easily in different secretions of the body This was shown for the first time by Wiman (1959) Our intention in this study has been to determine if the same applies to malignant tumours within the E N T area

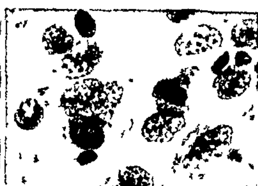
The execution of the cytochemical staining method is shown in Fig 17 By using trichloracetic acid (TCA) dissolved in 80 % ethyl alcohol as a fixating agent denaturation of the proteins is obtained which makes a maximum number of SH groups accessible for the reaction wit DDD Moreover



Figs 1-16 Exfoliative cytology in Otolaryngology. Different staining methods showing malignant cells

Papanicolaou: figs 2, 4, 6, 10, 12 and 14
May-Grünwald-Giemsa: figs 1, 5, 9, 11 and 13
Fluorochromation with acridine orange: figs 8 and 16
Protein-bound sulfhydryl groups (SH staining): figs 3, 7 and 15





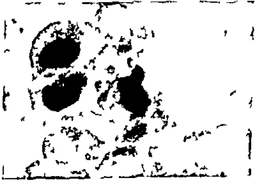
10





12





14





16

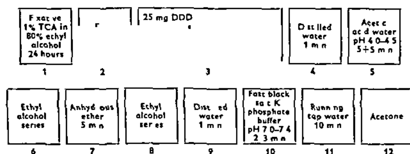


FIG 17 Staining procedure for the demonstration of sulfhydryl activity in exfoliated cells

TCA extracts glutathione cysteine and other free SH groups and prevents oxidation of other protein bound SH groups The alcohol series (Nos 2 and 8 in Fig 17) is composed of xylene absolute ethyl alcohol, 96 %, 80 % and 50 % ethyl alcohol while No 6 is the same series in reverse The preparation is submerged for 1 minute in each alcohol container Mounting can be done in Canada Balsam or Diatex

Fluorescence microscopy using acridine orange (AO)

In histology fluorescence microscopy has long been used for different purposes (Stubel 1911 Hamperl 1933 and others) Strugger (1949) was the first to describe the acridine orange method to distinguish between living and dead cells which gave green and red fluorescence respectively a fact which was used with yeast cells bacteria and spermatozoa The reliability of the so called Strugger effect has been strongly questioned by many authors however

The increased protein synthesis in malignant cells among others with increased concentration of desoxyribonucleic acid (DNA) in the cell nucleus and ribonucleic acid (RNA) in the cytoplasm and nucleolus is the basic cytochemical principle of the method described by von Bertalanffy & Bickis (1956) and von Bertalanffy Masin & Masin (1956) This technique allows for differential staining of the two nucleic acids RNA in the cytoplasm and nucleolus gives a bright red fluorescence DNA in the nuclear chromatin gives a green fluorescence *In cytological cancer diagnosis the screening is made* easier by the tumour cells strong fluorescence even if this is not specific for all forms of malignancy This original method has been somewhat modified later by Dart & Turner (1959) and Umiker Pickle & Waite (1959) In this study a technique described by von Bertanlanffy & Masin (1958) has been used (Fig 18)

A high pressure mercury vapour lamp (HBO220 Osram) was used as a source of light Between this and the object was interposed a blue exciter filter BG12 or alternatively BG3 and BG38 together allowing only ultra violet and blue light to pass and bring about a state of fluorescence in the object After preparation the superfluous external radiation was eliminated by suitable orange barrier filters Thus only fluorescent light emitted from



Fig 18 Acridine orange staining procedure for fluorescence microscopy

the slide preparation was allowed to pass and give the final picture to the observer

Of the greatest importance is the stain quality A British acridine orange preparation (G T Gurr, London) was found to be the most suitable for our purpose A stock solution of 0 10 % acridine orange (AO) is prepared in distilled water, which keeps indefinitely in the refrigerator For staining a portion of this solution is diluted with 1/15 M phosphate buffer of pH 6 to obtain a 0 01 % staining solution of AO, which also keeps for a long time The calcium chloride solution is necessary to produce differentiation between DNA and RNA fluorescence

The smears should be fixed immediately after preparation in equal parts of 95 % ethyl alcohol and ether Dried smears are also suitable but often show inferior morphology Formalin fixation should be avoided

The preparations are examined unmounted and wet under the microscope sometimes with a cover slip The fluorescence disappears however after 4–5 hr and ink marking on the cover slip of suspected cells is not possible Unmounted or mounted with Diatex the preparations can be kept for months and thereafter restained with AO After decolouring for 1–2 min in 50 % ethyl alcohol the slides can be restained with Papanicolaou s or some other morphological method

May Grunwald Giemsa staining procedure (MGG)

Staining of the cytological preparations according to this method has been performed in the following manner (Fig 19) The air dried or alcohol fixed

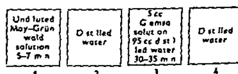


Fig 19 May–Grünwald–Giemsa staining procedure

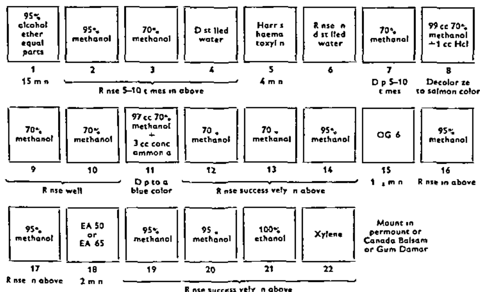


FIG 20 Papanicolaou staining procedure Flow chart

preparation has been submerged in May–Grunwald solution for 5–7 min (cytoplasm staining) has been rinsed in distilled water, stained 30 35 min in azureosin–methylene blue solution according to Giemsa (nucleus staining) and finally rinsed in distilled water Both the staining baths contain methyl alcohol which acts at the same time as a fixating and dissolving agent Preceding air drying is not necessary but the preparation can be submerged directly in the bath containing the May Grunwald solution The slides have been left unmounted which facilitates the final staining The storage properties have not been impaired in unmounted preparations The MGG staining gives some cytochemical information proteins containing desoxyribonucleic acid (DNA) are stained purple red while ribonucleic acid proteins (RNA) give a blue colour This fact can give some guidance in the diagnosis of cancer cells which often have a higher proportion of RNA in cytoplasm and nucleolus compared with other benign cells The most important advantage with the May–Grunwald–Giemsa method however is the clear and distinct morphology chiefly concerning the nucleus

Papanicolaou staining procedure

In exfoliative cytology this method has hitherto been the most frequently used particularly for material from the female genital tract and the respiratory system We have not used Papanicolaou s original technique (1942) here but worked with a later modification (Fig 20) which gives a beautiful polychromatic colour scale with good transparency The technique is widely known and does not require further description The preparations have been mounted in Canada Balsam The method has been worked out mainly with

the cytoplasm's different staining ability under normal and pathological conditions in view, properties which are important chiefly in the screening of a large material

RESULTS

Atypical cells with clear morphological criteria of malignancy according to established norms have been found in the majority of patients. Sample taking by direct wiping of the tumour surface has been shown to be a good method which has given cell rich smears. Sputum examination is the simplest method with tumours of the oral cavity and throat but has given preparations poor in cells compared with direct wiping or curetting.

The Papanicolaou staining and the MGG staining which have been performed parallel in all cases have both given good preparations. The latter has given distinct and well contrasted staining of chromatin structure and nucleolus, which is of decisive importance in diagnosis. The varying staining properties and details of the cytoplasm are more clearly presented with Papanicolaou's technique. We consider that the two staining methods compliment each other well. However, each is individually fully adequate for satisfactory cytological diagnosis in routine clinical work.

The method of acridine orange fluorescence microscopy is quick and simple to perform and suitable for use in otolaryngological cytological diagnosis. *Undifferentiated tumour cells and adenocarcinoma cells have* given a more or less brilliant red fluorescence on account of their high RNA concentration, while differentiated keratinized squamous cell carcinoma has not done so, but given an olive green appearance. However, the method gives only preliminary diagnosis of malignancy. Final diagnosis must rest on the basis of the morphology of the cells which is presented less well with this technique. *The AO method should thus not be used alone but always be* complemented with Papanicolaou or MGG staining.

Our investigation has shown that the sulfhydryl activity is low in normal cells exfoliated from the mucous membrane of the upper respiratory tract. Normal squamous epithelial cells, cylindrical cells, goblet cells, leucocytes and erythrocytes seem like pale shadows. The cancer cells, on the contrary, appear clear cut with clearly blue violet coloured nuclei, cytoplasm and nucleoli showing the high sulfhydryl activity (Figs. 3, 7, 15). This facilitates screening. Morphological details do not appear as clearly as with Papanicolaou and MGG staining.

Examples of malignant cells from commonly occurring tumours from various sites in otorhinolaryngology are shown in Figs. 1–16. The pictures illustrate the following stainings: Papanicolaou 2, 4–6, 10, 12, 14; MGG 1, 5, 9, 11, 13; sulfhydryl 3, 7, 15 and acridine orange fluorescence 8 and 16.

The case histories in the illustrated cases are briefly as follows.

CASE 1. A 64 year old man, who for four months had an enlarging ulcer in the mouth. On examination an ulcer approximately the size of a shilling was found with

surrounding firm infiltration in the mouth Samples for cytological examination were taken by direct wiping, which showed malignant cells of squamous cell type Histologically a *fairly well differentiated squamous cell carcinoma with keratinization was found* Treated by irradiation Submandibular gland metastases developed Died 6 months after treatment on account of another cancer in oesophagus (Figs 1, 2, 3, staining MGG, Papanicolaou and sulfhydryl)

CASE 2—A 55-year old man who in 1955 had had prolonged symptoms of otosalpingitis which after 9 months were shown to be due to cancer of the epipharynx Radiotherapy and neck dissection In 1958 recurrence in the epipharynx, for which palatal fenestration according to Wilson (1957) was performed to visualise the tumour, which was treated successfully by repeated electro coagulation In 1961 massive recurrence and growth through the base of the skull with resulting neurological symptoms Samples for cytological diagnosis were taken direct through the palatal fenestration and showed malignant cells (Figs 5, 6, 7, 8 staining MGG, Papanicolaou, sulfhydryl and AO) Biopsy showed a *poorly differentiated squamous cell carcinoma*

CASE 3—A 65 year old woman with 3 months' history of some difficulty in swallowing, increased mucus formation in the pharynx and increasing cough Examination revealed a large haemorrhagic ulcerated tumour in the left piriform fossa, extending into the back of the pharynx Secretions taken directly with a cotton wool swab via a short oesophagoscope The smears showed obviously malignant cells (Figs 9, 10 staining MGG and Papanicolaou) Simultaneous biopsy showed *a squamous cell carcinoma* with moderate keratinization Radiotherapy Six months after diagnosis glandular metastases developed in the neck, whereupon dissection of the neck was performed and further radiotherapy given Has been recurrence free for 1½ year

CASE 4—A 57-year old man who for 6 months had had increasing difficulty in swallowing and increasing loss of weight X ray revealed a stenosis suspected to be due to a tumour in the lower part of the oesophagus On oesophagoscopy at 30 cm from the upper incisors an extensive reddish polypoid haemorrhagic tumour was found Samples of secretions taken partly by cotton wool swab and partly by suction from the region of the tumour after preceding NaCl irrigation Preparations rich in cells were obtained by both methods A cytologically clear picture of carcinoma (Figs 13, 14, 15, 16 staining MGG, Papanicolaou, sulfhydryl, AO) Biopsy showed a *poorly differentiated adenocarcinoma* Surgical resection performed The patient died two weeks post operatively from sepsis and circulatory insufficiency

CASE 5—A 71 year old woman, who for four months had had discharge from the right ear A haemorrhagic polyp was found which completely filled the external meatus Biopsy excision performed at another hospital showed a *well differentiated squamous cell carcinoma* After admission to the Department of Radiotherapy smears of secretion from the external meatus were made which showed degenerated malignant cells of squamous type Treated with irradiation with initially a good result (Figs 11, 12 staining MGG and Papanicolaou)

CASE 6—A 75 year old man with pulmonary tuberculosis, pleurisy and cardiac failure One year previously operated on for adenocarcinoma of the thyroid In repeated cytological sputum examinations suspected tumour cells were found (Fig 4, staining Papanicolaou) but lung X rays showed healed tuberculous changes and pleurisy Later a metastasis the size of a pea from the thyroid carcinoma was extirpated from the vestibule of the nose which could be the explanation of the cells found in the sputum After 3 years with intermittent radioactive iodine treatment the lung X ray is unchanged and the patient free from local recurrence and metastases

the cytoplasm's different staining ability under normal and pathological conditions in view properties which are important chiefly in the screening *of a large material*

RESULTS

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Our investigation has shown that the sulfhydryl activity is low in normal cells exfoliated from the mucous membrane of the upper respiratory tract Normal squamous epithelial cells cylindrical cells goblet cells leucocytes *and erythrocytes seem like pale shadows The cancer cells on the contrary* appear clear cut with clearly blue violet coloured nuclei cytoplasm and nucleoli showing the high sulfhydryl activity (Figs 3 7 15) This facilitates screening Morphological details do not appear as clearly as with Papanicolaou and MGG staining

Examples of malignant cells from commonly occurring tumours from various sites in otorhinolaryngology are shown in Figs 1 16 The pictures illustrate the following stainings Papanicolaou *2 4 6 10 12 14* MGG 1 5 9 11 13 sulfhydryl *3 7 15* and acridine orange *fluorescence 8 and 16*

The case histories in the illustrated cases are briefly as follows

CASE 1 A 64 year-old man who for four months had an enlarging ulcer in the mouth On examination an ulcer approximately the size of a shilling was found with

Comparison between the morphological staining methods according to Papanicolaou and May-Grunwald-Giemsa has shown that both methods can be used with advantage in otorhinolaryngological cytological diagnosis. The MGG staining has in our experience given more detailed and better contrasted nuclear morphology which is shown in Figs. 1, 3, 9, 11, 13. This latter method has in addition the advantage of being a routine method in haematology and is therefore well established in all hospital laboratories. This makes the MGG method suitable for cytological advance examinations (prescreening) such as could be performed by practitioners or in smaller hospitals. If there is access to a cytological laboratory with specially trained staff Papanicolaou's staining method is preferable however, this being an international routine cytological method. With this method the degree of keratinization can be studied which is important for typing of squamous cell carcinoma. The nucleolus and chromatin structure appear distinctly as well and the varying staining ability and transparency is maintained.

We regard as an essential step forward in cytological diagnosis von Bertalanffy's acridine orange staining with fluorescence microscopy. In this the abnormal protein synthesis which characterises malignant cells is used for special staining. The method is a step on the path towards further differential staining where the aim is to give the malignant cells a colour which differs clearly from normal or inflammatory cells. In its simplicity this method is very valuable for prescreening and quick diagnosis. Cases with tumour suspect cells can later be sorted out with other morphological or cytochemical methods and with biopsy. Fluorochromation with acridine orange has however a definite disadvantage of both practical and theoretical significance. The basis for the red fluorescence in the cytoplasm is an increased concentration of RNA, a condition which is not always present in cells from a highly differentiated squamous cell carcinoma with much keratinization. Furthermore the RNA may even have disappeared as a result of cytolysis or necrosis. On the other hand there are benign cells with a high RNA content or normal cells (for example goblet cells) containing acid mucopolysaccharides which produce a red fluorescence. In these cases one turns therefore to morphological assessment which can be better performed by Papanicolaou's method or the MGG staining. The red fluorescence also disappears after 1-5 hr and mounting in a liquid plastic or Canada Balsam gives a disturbing autofluorescence. Microscopy is performed with or without a loosely applied cover slip which does not allow marking of suspected cells, a great practical and didactic drawback.

The idea of replacing inaccurate and time consuming morphological methods with a simple cytochemical technique has been developed in the sulfhydryl method. The increased sulfhydryl activity in malignant tumours has been known for a long time in cancer research. In exfoliative cytology this fact has been used first by Wurm in lung cancer diagnosis (1959, 1960, 1962). In our material malignant cells have been identified easily by their hyperchromasia and high concentration of protein bound sulfhydryl groups.

Normal squamous epithelium cells from the oral cavity and throat as well as sputum macrophages also show a high sulfhydryl activity but are distinguished from tumour cells by their different morphology The specificity of the method used with regard to protein bound sulfhydryl groups has been satisfactorily tested earlier by among others Barrnett & Seligman and Bahr In its present form it is inferior from the point of view of laboratory technique to the other three methods used on account of long fixation time (24 hr) and a proportionately long staining time (about 90 min) These times have been adhered to in the preliminary trials but later will probably be reduced considerably The staining solutions have also been prepared *ex tempore* to obtain the best results of staining The microscopic assessment can be done with a lower magnification than with morphological methods and is made easier by the unitary staining scale free from disturbing variety of colour and morphological details In this way both time and work are saved in routine cytological diagnosis which makes the method most suitable for a more comprehensive screening program possibly with automatic aids The increased sulfhydryl activity which characterises all rapidly growing tissue with increased protein synthesis is not specific for malignant processes a fact which parallels the uneven distribution of the nucleic acids in tumour cells and other cells with rapid growth and intensive albumin production In practice however one might be entitled to a certain extent to equate malignancy with the signs of the increased sulfhydryl activity Earlier clinical and experimental studies seem to support this assumption

Cytological examination of secretions from suppurating ears of longstanding is recommended by House (1949) for early detection of middle ear malignancy It is known that cancer in the middle ear is developed on the basis of a chronic suppurative otitis (Newhart 1917 Furstenberg 1924 Diamant 1941 Figi *et al* 1943) Malignant change appears to occur extraordinarily seldom however which is shown by House s report (1949) that at that time there had been described a total of only 200 cases Macrophages which are characteristic cells in secretions from acute otitis (Bryan 1953) but which can also occur in chronic otitis at times (Ojala & Palva 1955) can mislead *in the diagnosis of malignant cells In Figs 11 and 12 malignancy of cells* from the external meatus is illustrated clearly in a case of a chronically discharging ear In this case polypoid tissue could be seen otoscopically both in the middle ear and in the deepest parts of the external meatus with stenosis as a result and this aroused suspicion of malignancy The diagnosis could be made with certainty primarily by cytology and verified by biopsy which showed a well differentiated squamous cell carcinoma

The cytology of the oesophagus has been studied earlier to a limited extent by several investigators Principally two different methods for the taking of samples are described On the one hand blind oesophageal washings (Johnson *et al* 1955 Gephart *et al* 1959 Brandborg *et al* 1961) on the other hand direct wiping off or curettage from the tumour surface (Feltz & Probst 1953 Stahle & Wiman 1962) The latter method can only be perfor

med at the same time as oesophagoscopy, when the tumour can be inspected directly Oesophageal washing is an indirect method where samples are taken via a narrow catheter inserted via the nose to the desired level We have found that the taking of samples via the oesophagoscope with direct local wiping of the oesophagus wall gives preparations rich in cells and we regard this as the best method Aspiration of secretions from the tumour surface possibly after NaCl irrigation and certainly under full vision via the oeso phagoscope has also given satisfactory smears The 10 cases of histologically verified cancer of the oesophagus which we examined have all shown clear malignancy with both methods of obtaining samples With blind oesophageal washing the correct diagnosis (cancer) has been reached in 69 6 % (Johnson *et al* 1955) and 89 % (Gephart *et al*, 1959)

It is not possible to differentiate cytologically with certainty between oeso phagitis and cancer In severe longstanding cases of oesophagitis definitely abnormal cells have been described with large nuclei of irregular shapes, irregularities of chromatin pattern and abnormal large nucleoli, which can be misinterpreted as cancer (Johnson *et al*, 1955) Atypical large squamous cells with abnormal nuclear chromatin distribution and frequent multi nucleation have been observed to be exfoliated from the mouth, pharynx oesophagus and lungs in patients with untreated pernicious anaemia nutri tional folic acid deficiency anaemia and untreated megaloblastic anaemia of pregnancy (Brandborg *et al* 1961) The changes disappeared with specific therapy

If sputum is used for cytological diagnostic purposes in otorhinolaryngo logy, one should with positive finding of cells bear in mind a malignant process in the lower respiratory tract if no macroscopic changes can be found in the nose, throat oral cavity or larynx In such cases X ray examination of the lungs is indicated In pulmonary cytodiagnosis malignant cells can des cend from a silent tumour in the upper respiratory tract and thereby give misleading results This source of error is illustrated by Case 6 (Fig 4)

The effect of radiological treatment on mucous membranes and malignant tumours can be followed cytologically to a certain extent A succession of studies concerning gynaecological cytology during and after radiotherapy have been published Ruth Graham (1947) and Kjellgren (1958) have studied in detail the immediate effect of radiotherapy on exfoliated benign cells from the cervix and vagina Cellular and nuclear ballooning is characteristic and extensive vacuolisation of both the cytoplasm and the nucleus Multinuclea tion occurs and also bizarre cell forms From the radiation response of the cells certain prognostic conclusions can be drawn Cancer cells undergo the same changes in principle (Koss 1961)

There is also a persistent radiation effect on the squamous and endocervical epithelium which extends over several years This chronic effect differs somewhat from the acute but the changes are dominated still by cellular and nuclear enlargement Nuclear and cytoplasmic vacuolisation which is typical in acute irradiation damage is not present (Koss 1961)

Normal squamous epithelium cells from the oral cavity and throat as well as sputum macrophages also show a high sulfhydryl activity but are distinguished from tumour cells by their different morphology The specificity of the method used with regard to protein bound sulfhydryl groups has been satisfactorily tested earlier by among others Barrnett & Seligman and Bahr In its present form it is inferior from the point of view of laboratory technique to the other three methods used on account of long fixation time (24 hr) and a proportionately long staining time (about 90 min) These times have been adhered to in the preliminary trials but later will probably be reduced considerably The staining solutions have also been prepared *ex tempore* to obtain the best results of staining The microscopic assessment can be done with a lower magnification than with morphological methods and is made easier by the unitary staining scale free from disturbing variety of colour and morphological details In this way both time and work are saved in routine cytological diagnosis which makes the method most suitable for a more comprehensive screening program possibly with automatic aids The increased sulfhydryl activity which characterises all rapidly growing tissue with increased protein synthesis is not specific for malignant processes a fact which parallels the uneven distribution of the nucleic acids in tumour cells and other cells with rapid growth and intensive albumin production In practice however one might be entitled to a certain extent to equate malignancy with the signs of the increased sulfhydryl activity Earlier clinical and experimental studies seem to support this assumption

Cytological examination of secretions from suppurating ears of longstanding is recommended by House (1949) for early detection of middle ear malignancy It is known that cancer in the middle ear is developed on the basis of a chronic suppurative otitis (Newhart 1917 Furstenberg 1924 Diamant 1941 Figi *et al* 1943) Malignant change appears to occur extraordinarily seldom however which is shown by House s report (1949) that at that time there had been described a total of only 200 cases Macrophages which are characteristic cells in secretions from acute otitis (Bryan 1953) but which can also occur in chronic otitis at times (Ojala & Palva 1955) can mislead in the diagnosis of malignant cells In Figs 11 and 12 malignancy of cells from the external meatus is illustrated clearly in a case of a chronically discharging ear In this case polypoid tissue could be seen otoscopically both in the middle ear and in the deepest parts of the external meatus with stenosis as a result and this aroused suspicion of malignancy The diagnosis could be made with certainty primarily by cytology and verified by biopsy which showed a well differentiated squamous cell carcinoma

The cytology of the oesophagus has been studied earlier to a limited extent by several investigators Principally two different methods for the taking of samples are described On the one hand blind oesophageal washings (Johnson *et al* 1955 Gephart *et al* 1959 Brandborg *et al* 1961) on the other hand direct wiping off or curettage from the tumour surface (Pfaltz & Probst 1953 Stahle & Wiman 1962) The latter method can only be perfor

RNA Gehalt und bekommt olivgrune Fluoreszens ahnlich der, welche normale Zellen bekommen konnen Ein solches Verhalten begrenzt den Wert dieser Methode.

Die beiden cytochemischen Methoden, besonders die der Sulfhydrylaktivitatsbestimmung, haben sich als wertvolle Ergänzung zu den morphologischen Methoden erwiesen Die Diagnose kann jedoch noch nicht nur allein auf die hier angewandten cytochemischen Methoden gestutzt werden Sie eignen sich wohl gut fur „prescreening", die endgultige Diagnose muss jedoch weiterhin nach morphologischen Kriterien gestellt werden

Mehrere Cancerfalle werden mit verschiedenen Farbungsmethoden illustriert Die Untersuchung hat deutlich gezeigt, dass die Cytodiagnostik in der Oto Rhino-Laryngologie angewandt werden kann, und dort einen wesentlichen Beitrag zur raschen Diagnosenstellung liefert Die Methode ermoglicht auch die Fruhdiagnose von Cancer an anatomisch schwererreichbaren Stellen

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AN AUDIOMETRIC SURVEY OF THE INCIDENCE AND CAUSES OF HEARING DEFECTS AMONG DRAFTEES IN FINLAND, 1954–1955

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The hearing of 2071 draftees (aged 19) was tested with screening audiometry within the frequency range 250–4000 cps at 10 db level Hearing defects were found in 11 40 % of the testees (perceptive defects in 6 08 % and conductive in 4 20 %) The cause of hearing loss was established by otological examination The majority of the conductive hearing defects were caused by adhesive otitis media or chronic otitis media and sequelae 1 79 % of all testees had monaural or binaural adhesive otitis media and 2 12 % monaural or binaural chronic otitis media 0 63 % of the testees had lasting binaural hearing loss of at least 30 db in the better ear In more than half of these cases (8 out of 13) the hearing defect was caused by adhesive otitis media or chronic otitis media

It is concluded that, in order to decrease the incidence of permanent and disabling hearing defect caused by inflammation, it is of the utmost importance to test the hearing of schoolchildren regularly and audiometrically Emphasis is also laid on the importance of audiometric hearing tests at the beginning of military service, in order to detect perceptive hearing defect liable to deteriorate by acoustic trauma during military service

Young men of National Service age are often completely exempted from military service or detailed for special duties on account of diseases of the ear or hearing defects This is confirmed by the similarity of reports from all countries that have a standing army Although the criterion of normal hearing varies in different countries, it is possible to make a rough comparison of the incidence of disqualifying diseases of the ear in the armies of some countries This comparison is shown in Table 1

It is to be seen from Table 1 that although the incidence of disqualifying diseases of the ear varies considerably, it is generally speaking rather high Rowntree, McGill & Folk (1942) estimate that in the U S A, 4 6 % of the draftees were rejected because of aural diseases Hall (1951) reports that in England, between 1939 and 1942, 20 % of all draftees were exempted from military service and of the exempted 10 % had been rejected on account of diseases of the ear Of all aural diseases chronic inflammation of the middle ear seems to be the most frequent cause of rejection According to available statistics, this also seems to have been the case in the Finnish Army between 1929 and 1938 (Sotaväen Terveys, 1929–38) During this period, between

TABLE 1 *Incidence of draftees exempted from military service in England and the U S A on account of hearing defect or aural disease*

Year	Author	Country	Rejected ‰
1928	Crowden	England	48 38
1930–31	Crowden	England	53 97
1931–32	Crowden	England	51 20
1935	Berry	U S A 32)	13 52 14 72
1942	Rowntree McGrill & Folk	U S A 4)	44 5
1953–54	Lee	England	30

6 39 and 12 96 ‰ of all draftees were rejected at the preliminary medical examination because of hearing defect or diseases of the ear Most of these men (3 26–10 02 ‰) were rejected because of chronic double sided inflammation of the middle ear At the beginning of their service another 2 11–5 25 ‰ were rejected because of hearing defect or aural disease the majority (1 92–5 00 ‰) because of chronic inflammation of the middle ear Later, 1 23–3 35 ‰ were rejected because of aural disease, the majority (1 19–3 31 ‰) because of chronic inflammation of the middle ear

As Finland was at war during the years 1939–40 and 1941–44, it has not been possible to obtain reliable statistics for these periods On the other hand, it has been possible to obtain detailed statistics for the years 1946–54 These are shown in Table 2

A comparison of the information given in the statistics for 1929 38 and those for 1946–54 shows a marked decrease in the incidence of disqualifying aural disease among National Servicemen in Finland during the latter period Unfortunately an exact comparison is not possible, as the regulations in force for medical examinations differ for the two periods

TABLE 2 *Incidence of draftees in Finland rejected or exempted from military service on account of hearing defect or aural disease during the period 1946 54*

Year	Rejected at call up or during service on account of hearing defect or aural disease ‰	Rejected at call up or during service on account of chronic otitis media ‰
1946	3 58	2 25
1947	3 09	1 85
1948	3 39	1 52
1949	3 51	1 33
1950	4 20	1 51
1951	5 00	1 29
1952	4 03	1 08
1953	4 82	1 37
1954	3 84	1 54

Survey Carried Out by the Writer

At military medical examinations in Finland hearing is usually tested by speech and whisper tests These tests have been subjected to strong criticism during recent decades and have been severely condemned by many people (Holmgren 1939 Fowler 1940 1947 Harris 1946 Trowbridge 1947 Glorig 1949 Fletcher 1953 Flottorp 1955) These authors all lay emphasis on the fact that the noise level of the testing room affects the intensity of the tester s speech and whispers without the tester himself noticing it It has been shown that the intensity of a whisper may vary considerably so that the distance up to which it can be heard can vary as much as 200 % (Fowler 1947) Moreover the acoustic qualities of the testing room play a great part in the audibility of a whisper (Davis 1947 Watson & Tolan 1949)

Therefore the demand for more accurate methods e g pure tone audiometry has grown rapidly In 1938 Newhart s method for audiometrical group testing of hearing was introduced This sweep check or screening method has proved to be both quick and reliable

Provided calibration is correct the audiometer always measures hearing in the same way loss of hearing being given exactly in a physical unit Another advantage of the pure tone audiometer test is that slight but from a prognostic view important hearing defects can be detected A comparison of different testing methods has clearly shown the superiority of the audiometer (Lundgren 1948 Holmgren 1952 Lumio 1957) Fowler (1947) has emphasized the importance of testing the hearing of servicemen with the audiometer method

To my knowledge there are no reports in the literature about audiometric group testing of the hearing of young men of National Service age It was therefore of interest to compare such a test with a similar audiometric group test made among schoolchildren in Finland during the years 1953 56 (Juselius 1958)

At the suggestion of Docent Colonel Harry Bjork M C the author tested the hearing of draftees aged 19 with the aid of a pure tone audiometer The testing which concerned 2071 men took place at the medical inspection in connection with drafting for service in September 1954 and 1955 and was carried out in two different areas One covered the Military District of Vasa (1935 age group) and the other the whole of the Military District of Northern Nyland and part of the Military District of Southern Nyland (1936 age group) The material was thus homogeneous consisting exclusively of young men of the age of nineteen who according to the National Service Law must report for service at that age Fig 1 shows the districts where the survey was carried out

A pure tone audiometer (Peters type SPD 3) was used for the testing It was checked beforehand by taking a normal audiogram of 15 people with normal hearing After the tests the audiometer was checked at the State Technical Research Centre Fig 2 shows the control graph of the audiometer

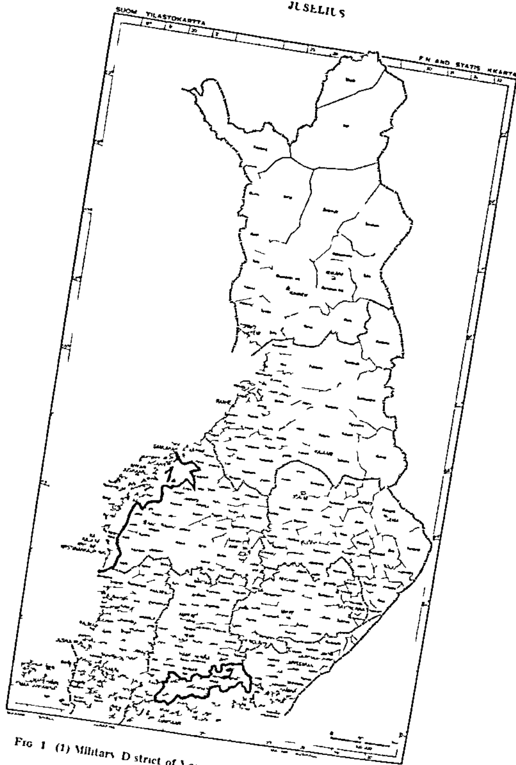


FIG 1 (1) Military District of Vasa (2) Military District of Nyland

e hearing tests were carried out by the writer himself in a quiet room he screening method was employed The screening was within the ney range of 250–4000 cps at an intensity level of 10 db No sound

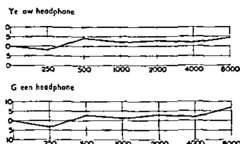


FIG 2 The normal graph of the audiometer compared with the O line of the National Bureau of Standards

proof room was available but it was always possible to find a room where the testing was not disturbed by external noises The testee was placed with his face turned away from the audiometer and was told to signal when he heard the sound by raising his right or left hand according to which ear was being tested To eliminate dissimulation the pure tone signals were arbitrarily changed from one ear to the other They were given at different intervals and were of varying duration Only a few attempts at simulation occurred The hearing of testees who heard all pure tones with an intensity of 10 db was regarded as normal A hearing loss of at least 15 db or more for two of the test tones between 250 cps and 2000 cps or at least 20 db for the tone 4000 cps was considered pathological

All testees who according to these standards had a hearing loss were subjected to a detailed oto rhinological examination comprising speech and whisper tests as well as a complete air conduction audiogram within the frequency range 250 8000 cps and a bone conduction audiogram within the frequency range of 250–4000 cps The condition of the eardrum was ascertained and if an adhesive otitis was suspected Brunings Siegle s pneumatic ear speculum was used If adhesive otitis or tubal occlusion was suspected tubal inflation was performed after which hearing was again checked with the audiometer If necessary tuning fork tests were used

RESULTS

The overall incidence of hearing defects among the testees is shown in Table 3 which shows the incidence of hearing defect in the group as a whole as well as in the two separate districts

Table 4 shows the incidence of conductive and perceptive hearing defects as well as the incidence of different aural diseases causing hearing defects according to the total number of ears defective in hearing

Diagnoses

Otosalpingitis

All cases of tubal occlusion have been placed under this heading [illegible]l insufflation with or without myringotomy, restored or noticeably im[illegible]d

Table 3 *Incidence of audiometrically diagnosed monaural or binaural hearing defect among draftees in Finland 1954–55*

The tests were carried out in two districts

Military district	No tested	Total no of men with hearing defect	Men with monaural hearing defect	Men with binaural hearing defect
Vasa	992	120 (12 10 %)	69 (6 96 %)	51 (5 14 %)
Nyland	1079	116 (10 75 %)	68 (6 30 %)	48 (4 45 %)
Total	2071	236 (11 40 %)	137 (6 62 %)	99 (4 78 %)

Table 4 *Causes of hearing defects (250–4000 cps) among National Servicemen in Finland, 1954 55*

	No of ears
A Hypacusis conductiva	
1 Cerumen	6 (1 8 %)
2 Otosalpingitis	30 (8 9 %)
3 Otitis media adhaesiva chronica	58 (17 3 %)
4 Otitis media suppurativa chronica et residua	52 (15 6 %)
5. *Hypacusis conductiva e causa ignota*	4 (1 2 %)
	150 (44 8 %)
B Hypacusis perceptiva	185 (55 2 %)
	335 (100 0 %)

hearing Thus this group comprises only those cases in which the prognosis has been considered good

Otitis media adhaesiva chronica

This group includes cases where an obvious and verifiable (with Brunings Siegle s speculum) adhesive process existed and where, after tubal inflation *no, or only a very slight, improvement in hearing could be noted, in spite of* an open Eustachian tube

Otitis media suppurativa chronica et residua

This group includes cases with chronic suppuration in the middle ear as well as cases with dry eardrum defect or sequelae of an operation for *chronic suppuration*

Hypacusis conductiva e causa ignota

All ears with conductive hearing loss which do not come under any of the other headings have been placed in this group

Hypacusis perceptiva

This group comprises ears with normal eardrum findings and perceptive hearing loss If signs of perceptive hearing loss occurred in connection with

TABLE 5 *Incidence of curable and lasting hearing defect among National Servicemen in Finland, 1954–55*

	Total no of men with hearing defect	Men with monaural hearing defect	Men with binaural hearing defect
No tested 2071 men			
Curable	26 (1.26 %)	16 (0.77 %)	10 (0.48 %)
Lasting	210 (10.14 %)	121 (5.84 %)	89 (4.3 %)

TABLE 6 *Causes and incidence in lasting hearing defects among 2071 National Servicemen in Finland, 1954–55*

Distribution in the two districts and in the whole group

	Otitis media adhaesiva chronica	Otitis media suppurativa chronica	Hypacusis conductiva e causa ignota	Hypacusis perceptiva
Military district of Vasa (No tested 992)				
Men with lasting monaural or binaural hearing defect	19 (1.92 %)	27 (2.72 %)	1 (0.10 %)	59 (5.95 %)
Military district of Nyland (No tested 1079)				
Men with lasting monoural or binaural hearing defect	18 (1.67 %)	17 (1.58 %)	2 (0.19 %)	67 (6.21 %)
Total (No tested 2071)				
Men with lasting monoural or binaural hearing defect	37 (1.79 %)	44 (2.12 %)	3 (0.14 %)	126 (6.08 %)
Men with lasting binaural hearing defect	19 (0.92 %)	11 (0.53 %)	1 (0.05 %)	58 (2.80 %)

an obvious adhesive otitis media or chronic suppuration of the middle ear, the perceptive hearing defect has been considered as secondary and the cases in question have been classified as conductive hearing defects In this group there are a considerable number of isolated hearing defects of the c⁵ dip type

The incidence of curable and lasting hearing defects is shown in Table 5

Hearing defects of the groups cerumen and otosalpingitis are classified as curable Hearing defects caused by otitis media adhaesiva chronica otitis media suppurativa chronica et residua hypacusis conductiva e causa ignota and hypacusis perceptiva have been classified as lasting The possibility of improving hearing by operative methods or hearing aids has not been taken into consideration here

TABLE 7. *Incidence of lasting binaural hearing defect of varying degree among National Servicemen in Finland, 1951–55*

Classified according to hearing loss in the better ear within the frequency range 250–4000 cps

No. tested	<30 db	30–60 db	>60 db
2071	76 (3.67 %)	11 (0.53 %)	2 (0.10 %)

The causes and incidence of lasting hearing defects in each district as well as in the whole group are shown in Table 6. The causes of lasting binaural hearing defects in the whole group are also to be found in this table.

Table 7 shows the incidence of draftees with varying degrees of lasting binaural hearing loss. They have been classified according to the degree of hearing loss in the better ear in the frequency range 250–4000 cps.

Table 8 gives a report of cases with lasting relatively severe binaural hearing defects. The loss is given in decibels within the speech range 250–4000 cps, as well as in the most important speech range 500–2000 cps. Hearing loss for both the better and the worse ear is shown in Table 8 as well as the cause of the impaired hearing.

DISCUSSION

1. *An analysis of available statistics seems to show that in Finland the* incidence of draftees who were exempted from military service on account of hearing defect or aural diseases, was much greater during the period 1929–38 than during the period 1946–51. Moreover the incidence of chronic *middle ear inflammation seems to have been considerably lower during the* second period (1946–51).

This decrease may have been due to a higher standard of living and to an improved Public Health Service and perhaps to improved therapeutic facilities after the introduction of sulfonamides at the end of the thirties.

2. The results of the tests carried out by the writer in two different parts of the country show a remarkable similarity. Only in the incidence of permanent hearing defect caused by inflammation can any difference be seen. The incidence of adhesive otitis (1.92 %) and chronic otitis media (2.72 %) is greater in the Military District of Vasa than in the Military District of Nyland where the corresponding figures are 1.07 % and 1.58 %. This difference may possibly be due to the fact that at the time of the survey there was no otologist in the province of Vasa while most of the otologists in the country had been working in Nyland for several decades.

3. 55.2 % of the recorded hearing defects were perceptive and 44.8 % conductive. The majority of the conductive hearing defects consisted of adhesive otitis media and chronic otitis media with sequelae. The results of an examination of schoolchildren carried out by the writer in the period

TABLE 8 *Men with lasting, relatively severe deafness Degree and cause of deafness*

	Hearing loss within frequency range 250–4000 cps in db	Hearing loss within frequency range 500–2000 cps, in db	Diagnosis
Better ear	38	38.3	Hypacusis perceptiva
Worse ear	38	38.3	
Better ear	40	40	
Worse ear	44	40	
Better ear	41	40	
Worse ear	48	48.3	
Better ear	31	31.6	
Worse ear	45	45	
Better ear	30	31.6	
Worse ear	31	31.6	
Better ear	33	31.6	Otitis media suppurativa chronica
Worse ear	65	65	
Better ear	41	45	Status ex operatione radicali auris mediae
Worse ear	48	50	
Better ear	62	65	Residua post otitim cum perforatione persistente membranae tympani Status ex operatione radicali auris mediae
Worse ear	65	68.3	
Better ear	68	66.6	Residua post otitim cum perforatione persistente membranae tympani Otitis media suppurativa chronica
Worse ear	78	80	
Better ear	38	36.3	Otitis media adhaesiva chronica
Worse ear	38	38.3	
Better ear	30	35	Residua post otitim cum perforatione persistente membranae tympani
Worse ear	44	43.3	
Better ear	33	35	Otitis media adhaesiva chronica
Worse ear	34	36.6	
Better ear	32	33.3	Otitis media suppurativa chronica
Worse ear	38	43.3	

1953–56 differed considerably in this respect Only 14.4 % of all recorded hearing defects were perceptive The explanation is to be found in the more frequent occurrence of otosalpingitis in children

4 Hearing defects among National Servicemen were lasting in 10.14 % of the cases, while 1.26 % were curable Among the schoolchildren tested by the writer during the period 1953 56, there were 5.40 % curable and 2.28 % lasting hearing defects — a striking difference again due to the higher percentage of otosalpingitis in children

Table 9. *Comparison of causes of lasting hearing defect among schoolchildren in Finland (1953–56) and among National Servicemen in Finland 1954–55*

	Otitis media adhaesiva chronica	Otitis media suppurativa chronica	Hypacusis conductiva e causa ignota	Hypacusis perceptiva
Children (aged 7–14)				
Tested 13 746				
Lasting monaural or binaural hearing defect	72 (0.52 %)	92 (0.67 %)	7 (0.05 %)	143 (1.04 %)
Lasting binaural hearing defect	13 (0.09 %)	10 (0.07 %)	2 (0.01 %)	68 (0.49 %)
National Servicemen (aged 19)				
Tested 2071				
Lasting monaural or binaural hearing defect	37 (1.79 %)	44 (2.12 %)	3 (0.14 %)	126 (6.08 %)
Lasting binaural hearing defect	19 (0.92 %)	11 (0.53 %)	1 (0.05 %)	58 (2.80 %)

5. Among the National Servicemen tested 4.06 % had lasting monaural or binaural conductive hearing defects, while 6.08 % had a perceptive loss in one or both ears. Among the schoolchildren tested 1.24 % had lasting conductive hearing defects in one or both ears, while 1.04 % had perceptive hearing losses. The difference is remarkable, and the survey of school children shows that an encouraging change for the better in the incidence of lasting hearing defects (adhesive otitis media and chronic otitis media and sequelae) set in during the fifties in Finland. For the sake of clarity a comparison of the results of the writer's two surveys (among schoolchildren and National Servicemen) is given in Table 9.

The main cause of the absolute as well as the relative greater incidence of perceptive hearing defects among youths of National Service age is due to the fact that high tone losses occur more frequently in the male sex (Ciocco 1936, Guild 1940, Lundgren 1948, Curry 1950). This fact was also noted in the writer's survey of schoolchildren (Juselius 1958).

6. The incidence of lasting binaural hearing losses was noticeably greater among the National Servicemen than among schoolchildren. The results of the two surveys are compared in Table 10, where it can be seen that the incidence of lasting binaural hearing defect of 30–60 db within the frequency range 250–4000 cps is about five times greater among National Servicemen than among schoolchildren. The incidence of severe hearing defect of more than 60 db is ten times greater among National Servicemen than among schoolchildren.

7. The more serious lasting binaural hearing losses among the draftees tested were caused by adhesive otitis media or chronic otitis media and its sequelae in more than half the cases, i.e. in 8 cases out of 13 (Table 8). The results of the writer's survey of schoolchildren were quite different in this respect. Out of 16 children with lasting binaural hearing loss of at least

TABLE 10 *Incidence of men with varying degrees of lasting binaural hearing defect among National Servicemen in Finland, 1954–55 compared with the corresponding incidence among schoolchildren in Finland, 1953–56*

Classified according to the hearing loss in the better ear in the frequency range 250–4000 cps

	Total tested	<30 db	30–60 db	>60 db
Schoolchildren (aged 7–14)	13 746	77 (0.56 %)	15 (0.11 %)	1 (0.01 %)
National Servicemen (aged 19)	2 071	6 (3.67 %)	11 (0.53 %)	2 (0.10 %)

30 db within the frequency range 250–4000 cps only 4 had a hearing defect caused by inflammation the other 12 having perceptive defects

CONCLUSIONS

The high incidence of permanent hearing defect caused by inflammation among National Servicemen in Finland (3.8 %) emphasizes the importance of testing the hearing of children Antibiotics alone cannot be relied on to decrease the high incidence of permanent hearing defect caused by inflammation This applies in particular to cases of adhesive otitis most of which have no doubt developed from neglected otosalpingitis in childhood Regular audiometric hearing tests during the first school years are the only means by which it is possible to discover and treat inflammatory aural diseases in time — diseases which may later develop into permanent and incapacitating hearing defects

The high incidence of perceptive hearing defects among the draftees (6.08 %) seems to emphasize the importance of audiometric hearing tests either on call up or at the beginning of military service as there is a considerable danger of deterioration of perceptive hearing loss during military service during which there are always risks of acoustic trauma

ZUSAMMENFASSUNG

Das Gehör von 2071 Wehrpflichtigen (Alter 19) wurde audiometrisch im Frequenzbereich 250–4000 Hz bei einer Intensität von 10 db geprüft Hördefekte wurden bei 11.40 % der Geprüften festgestellt (Perzeptionsschwerhörigkeit bei 6.08 % und Schalleitungsschwerhörigkeit bei 4.20 %) Die Ursache des Hörverlustes wurde durch otologische Untersuchung festgestellt Die Mehrzahl der Fälle von Schalleitungsschwerhörigkeit waren von Adhäsivprozesse chronische otitis media und deren Folgezustände verursacht In 1.79 % der untersuchten Fälle trat monaurale oder binaurale adhäsiv-otitis auf und in 2.12 % monaurale oder binaurale chronische otitis media In 0.63 % der geprüften Fälle kam bleibender binauraler Hörverlust von wenigstens 30 db des besseren Ohres vor In mehr als 50 % dieser Fälle (8 von 13) verursachte adhäsiv otitis oder chronische otitis media den Hörverlust

Es wird festgestellt dass um das Vorkommen bleibender und invalidisierender, durch Entzündung verursachter Hörverluste zu vermindern es von grosster Wichtig

keit ist, das Gehör der Schulkinder regelmässig und audiometrisch zu prüfen Nachdrücklich wird auch die Wichtigkeit audiometrischer Gehörprüfungen junger Männer bei der Einberufung zum Heeresdienst betont, um Perzeptionsschwerhörigkeit zu entdecken, die geneigt ist, sich während des Heeresdienstes zu verschlechtern

ACKNOWLEDGEMENTS

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To the Surgeon General, Finnish Defence Forces, Major General Pekka Somer, M C, the writer would like to express his deep gratitude for all the invaluable help afforded in permitting and facilitating the testing of the National Servicemen

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ANGULAR LOCALIZATION

A clinical test for investigation of the ability to locate airborne sound

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The investigation was carried out to develop a method for directional audiometry that will provide a test of the different functions in angular localization. The method has the following properties: (1) What we have called "physiological directional hearing", i.e. the ability to angular localization of a sound source in a free field, can be estimated. (2) Defective ability to discriminate interaural time, phase and intensity differences can be detected individually. The sources of error of the method are carefully investigated with the aid of an artificial head.

In future work this method for directional audiometry will be tested clinically in order to estimate the value angular localization may have for the topical diagnosis of hearing defects.

Directional hearing, i.e. the ability of an observer to judge the direction of a sound source, is one of the most important auditory functions in the majority of mammals. It helps them in avoiding danger as well as in hunting their prey. Directional hearing is important in everyday life for people as one of the major hearing functions: it helps them to orientate themselves, to localize vehicle horns in traffic, etc. Some human beings are especially dependent on directional hearing: seamen, aviators and musicians, and the blind. Stereo hearing is also of interest from a theoretical viewpoint and therefore many research workers in various fields have devoted a great deal of interest to the subject. This activity has occurred in the field of medical audiology, where problems connected with directional hearing have attracted great attention in recent years because binaural hearing tests, for example directional audiometry, are considered to be of help in the topical diagnosis of defective hearing (Greene 1929, Sanchez Longo & Forster 1958, Matzker & Welker 1959, Hahlbrook & Schmidt 1960). Several methods have been developed for the investigation of directional hearing (Greene 1929, Jongkees & Groen 1946, Matzker 1959).

The literature in question includes two main types of methods for the investigation of directional hearing: (1) using earphones and (2) free field tests.

The first mentioned methods are of the following type. Subjects equipped

with earphones have been set to listen to stimuli with variable differences of time phase and intensity between the ears and have subsequently been requested to describe their reaction to the various sound impressions With suitably selected differences the sensation of sound can take the form of an imaginary sound source i e a phantom source which exists in the head of the listener or in its close proximity Tests of this type have been carried out by many research workers for example Matzker Some of the most significant advantages of this method include the simple laboratory equipment and the possibility of judging the capacity of discriminating interaural time phase and intensity differences individually The interaural differences (1) time (2) phase and (3) intensity form the physical background to the ability to carry out angular localization of a sound In the case of directional audiometry with earphones it is possible for example to maintain constant interaural intensity and vary the time difference or vice versa The same applies to the phase and intensity factors when pure tones are used as stimuli This means that the earphone method can be used to differentiate each factor individually and judge the ability of the subject to notice these interaural acoustic variations The great disadvantage of this method is however that the subject localizes the sound source in his head or in its close proximity This implies that by no means the same degree of accuracy of direction is obtained as in the case of physiological condition i e when the sound is presented in free field It is also open to question whether it is the same thing that is being investigated since in one case the sound source is located inside the head and in the other case the sound is in the room In 1959 Matzker described a method of the earphone type for use in the diagnosis of central auditory defects The patient uses the earphones to listen to an intermittent (8 pulses per sec) sinusoidal tone of variable frequency When the stimulus from one earphone is delayed the sound source seems to move towards the other ear Matzker has used different tones and considers that he has examined the ability to carry out localization at different frequencies According to Matzker it must therefore be possible to discriminate a phase difference at frequencies above 1400 cps However it has been shown by Zwislocki & Feldman (1956) Klumpp (1956) and Mills (1958) that the ears are only sensitive to interaural phase differences at frequencies lower than 1400 cps The fact that Matzker still obtained a directional impression at higher frequencies depends probably on secondary sounds in the form of clicks in the apparatus Stevens & Newman indicated as early as 1936 that it was essential that clicks were reduced as much as possible during localization tests with pure tones since the clicks were easier to localize than pure tones This means that it is the same thing that is investigated in the Matzker test i e the ability to discriminate interaural time differences The Matzker method however has proved valuable in the topical diagnosis of auditory impairments

Angular localization tests of the other type are carried out in the following way The subject listens to a sound source in free field and states the direction of the source The disadvantages of this method are that expensive laboratory

equipment is essential and that it is not possible to differentiate interaural time phase and intensity differences as was the case in the earphone test The great advantage is however that it is only in this type of test that the subject obtains a physiological stereo impression i e locates the sound source to the place where it actually is It is thus the physiological directional hearing that is tested and judged with this type of method

Lloyd A Jeffress (1955) has described such a method where the sound is presented in free field The tests were carried out in an anechoic chamber where three loudspeakers were mounted in front of the subject A fourth loudspeaker was mounted on an arm that the subject himself can move the experimenter regulates the others Signals are sent out from one of the fixed loudspeakers alternately with a noise from the movable loudspeaker and the task of the subject is to move the loudspeaker he controls so that the signals from the loudspeakers come from the same direction This method has been mainly used for basic research studies The great advantage is that the test concerns hearing alone i e none of the other senses of the subject is used to carry out the test The great disadvantage of the method is that the actual ability to localize sound is not measured Since the subject is required only to match the apparent positions of the two sound sources his impression of their location may be quite erroneous without that fact being revealed by the test

Jongkees *et al* (1958) have also described a physiological method for sound localization tests the sound being presented in free field Several loudspeakers are placed along a graduated arc shaped scale The patient is placed with his head in a fixed position in the centre of the arc and is asked to close his eyes The experimenter then actuates a signal from one of the loudspeakers and the patient indicates the direction from which he thought the sound came This procedure is repeated using the various loudspeakers at random Only one frequency 1000 cps is used and as a result of this this method only provides information concerning the ability to localize this frequency Jongkees used this method to examine various types of hearing defects and obtained interesting results including the inability of fenestrated patients to localize sound This method gives an incomplete picture of directional hearing however as shown by the fact that three unilaterally deaf subjects were shown to have normal directional hearing Directional hearing is mainly a binaural function so that these patients must have had a greatly reduced directional hearing

In an earlier paper the physical factors in angular localization were studied (Nordlund 1962) On the basis of this investigation a method for the examination of directional hearing has been developed This method has two major advantages

(1) What we have called physiological directional hearing is investigated i e the ability to angular localization of a sound source in a free field
(2) Defective ability to discriminate interaural time phase and intensity differences can be detected individually

Directional hearing tested by this method will thus provide a picture of the different functions in angular localization In future work this method for directional audiometry will be tested clinically in order to estimate the value angular localization may have for the topical diagnosis of hearing defects

APPARATUS

In an anechoic chamber A and an adjacent control room B the following apparatus is set up (see Fig 1) In the anechoic chamber there is a motor located under the subject (1) The motor is connected to an arm (4) which runs along a 140° graduated scale (2) The motor, which can rotate in both directions, is connected to a directional indicator (6) whereby the angle described by the motor arm relative to the scale can be read off in the control room On the motor arm behind the scale there is a loudspeaker (3) (artificial voice type 4215, Bruel & Kjaer) This is connected to a sound generator (7) and a noise generator (8) In the anechoic chamber there are also two loud speakers (5), used for masking These are connected to the noise generator (8) When the motor starts the noise is automatically switched on for 8 sec

PROCEDURE

First the subject is given a brief description of how the tests are carried out The subject is informed that there is a loudspeaker running on a movable mounting and that this loudspeaker can be moved to any point on the scale Whenever the loudspeaker is moved a masking noise starts at the same time to prevent the sound of the motor from being audible This masking noise always has the same duration and the subject therefore gets no clue as to the distance that the loudspeaker has been moved along the scale About 2 sec after this noise has ceased there is a test signal with a duration of 5 sec from the loudspeaker at the scale During these 5 sec the subject turns his head in both directions in an attempt to determine the direction of the sound source He then describes the direction of the signal by stating the number on the scale After receiving this information the subject is placed in the anechoic chamber with his head in the centre of the graduated scale (see Fig 1) The experimenter sits in the control room from where he moves the loudspeaker at random While it is moving the masking noise starts automatically and when this has ceased the experimenter waits for about 2 sec after which the loudspeaker at the scale is switched on with the signal in question The movable loudspeaker is arranged so that the signal has an automatic duration of 5 sec and when the signal is in the form of a tone it starts and ceases without any audible click The experimenter reads off the directional indicator and thus obtains the position of the loudspeaker relative to the scale and also notes the direction stated by the subject In this way the angle of error of the subject can be determined for various signals

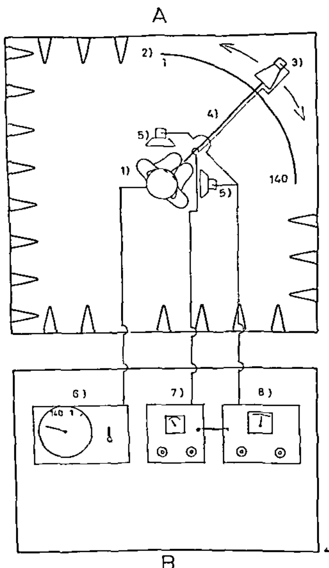


Fig 1 Apparatus used *A* Anechoic room *B* Control room (1) Subject (2) arc shaped scale graduated from 1° to 140 (3) movable loudspeaker (4) motor arm on which the movable loud speaker is fitted (the motor is located under the subject) (5) masking loudspeakers (6) apparatus to read off the position of the loud speaker and to control the movement of the loudspeaker (7) signal generator (8) noise generator

SOURCES OF ERROR

An important point in these tests is that the interaural acoustic differences making possible angular localization are not influenced by the method used It is thus essential that the interaural time phase and intensity differences forming the background for angular localization actually occur in the ears of the subject for various azimuths of the sound source

Directional hearing tested by this method will thus provide a picture of the different functions in angular localization. In future work this method for directional audiometry will be tested clinically in order to estimate the value angular localization may have for the topical diagnosis of hearing defects.

APPARATUS

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PROCEDURE

First the subject is given a brief description of how the tests are carried out. The subject is informed that there is a loudspeaker running on a movable mounting and that this loudspeaker can be moved to any point on the scale. Whenever the loudspeaker is moved a masking noise starts at the same time to prevent the sound of the motor from being audible. This masking noise always has the same duration, and the subject therefore gets no clue as to the distance that the loudspeaker has been moved along the scale. About 2 sec after this noise has ceased there is a test signal with a duration of 5 sec from the loudspeaker at the scale. During these 5 sec the subject turns his head in both directions in an attempt to determine the direction of the sound source. He then describes the direction of the signal by stating the number on the scale. After receiving this information the subject is placed in the anechoic chamber with his head in the centre of the graduated scale (see Fig. 1). The experimenter sits in the control room from where he moves the loudspeaker at random. While it is moving the masking noise starts automatically and when this has ceased the experimenter waits for about 2 sec after which the loudspeaker at the scale is switched on with the signal in question. The movable loudspeaker is arranged so that the signal has an automatic duration of 5 sec, and when the signal is in the form of a tone it starts and ceases without any audible click. The experimenter reads off the directional indicator and thus obtains the position of the loudspeaker relative to the scale and also notes the direction stated by the subject. In this way the angle of error of the subject can be determined for various signals.

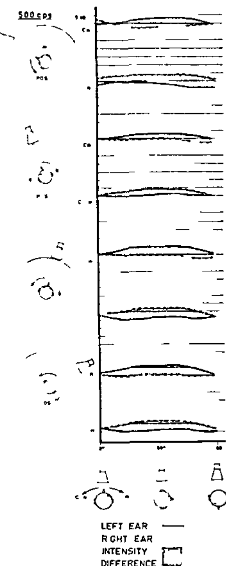


Fig. 3

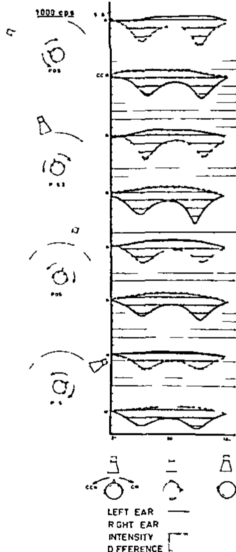


Fig. 4

Figs. 3–7. Investigation of variations in intensity (ordinate) in the right and the left ear during both clockwise and counterclockwise rotation (abscissa = azimuth) of the artificial head in the place of the subject at different frequencies and loudspeaker positions.

different loudspeakers. The loudspeaker to be examined was placed in the anechoic chamber on a vertical motor shaft so that it could be rotated. During rotation the sound intensity was recorded at a distance of 90 cm from the loudspeaker. Fig. 2 shows the curves obtained from such measurements when the artificial voice was tested. It can be seen that the intensity is rela-

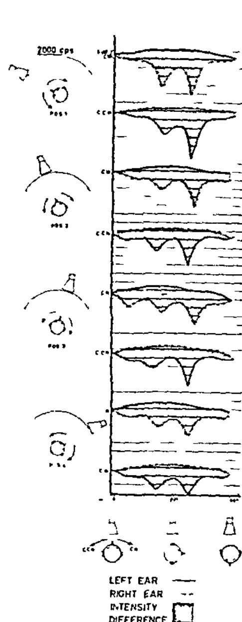


Fig 5

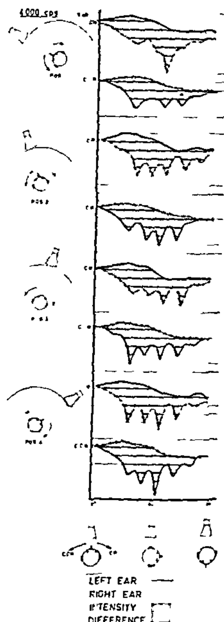


Fig 6

tively constant at a distance of 90 cm from the loudspeaker, independent of the direction it is facing as long as the observer remains within 20° of its centre axis This implies that the sound field in the zone where the head of the subject is to be located is spherical for the frequencies being examined with this loudspeaker The other loudspeakers examined were found to have more irregular sound fields and therefore unsuitable for directional audiometry

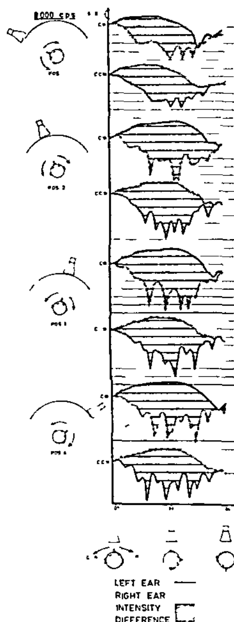


Fig 7

Intensity measurements in the anechoic chamber showed that the intensity of the sound decreased by approximately 6 db when the distance from the loudspeaker was doubled as it should if no echo was present, and the room could be regarded as free field It was found, however, that the sound field of the loudspeaker changed when it approached the walls in the anechoic chamber

An artificial head of standard size with microphones fitted in the place of the eardrums (Lidén & Nordlund 1962) was set up in the centre of the graduated scale, i.e. the place where the head of the subject was to be. The microphones in the head of the model were connected over cathode followers, microphone amplifiers and filters to a level recorder. This made possible continuous recording of the intensity at the location of the eardrums for different signals from the loudspeaker along the scale. Since the head was fitted on a vertical motor shaft it could be rotated in both directions at a constant speed so that the angle of incidence (azimuth) of the signal at the head model varied. Turning was then carried out at the same time as the intensity was recorded and in this way the variation of intensity at the ear drums was obtained as a function of azimuth. This intensity function was examined at the frequencies 500, 1000, 2000, 4000 and 8000 cps. Tests were carried out with the loudspeaker at four different positions along the scale in order to see whether this had any influence on the result. The positions of the loudspeaker were behind the scale marks 10°, 50°, 90° and 130° which were selected as representative points. The head model was rotated both clockwise and counterclockwise from 0° to 180°. The results obtained are illustrated in Figs. 3–7. These show the relative intensity in the ears as a function of azimuth at four different positions of the loudspeaker. It can be seen that the curves for the same frequency have a similar form independent of the position of the loudspeaker. There are, however, variations between measurements carried out for various loudspeaker positions and these are most obvious at the frequency 8000 cps. This means that there has been a change in the loudspeaker sound field depending on the fact that it has been moved to different positions along the scale. In order to make a closer examination as to whether the modified sound field is dependent on the position of the loudspeaker the following tests were carried out.

As in the case of the previous tests the head model was placed in the centre of the graduated scale and fitted on the vertical motor shaft (Figs. 8, 9). In this case, however, the motor shaft was connected to the movable loudspeaker behind the scale, i.e. the head and the loudspeaker formed a fixed system relative to each other. When the loudspeaker was moved along the scale the head also rotated so that the initial relationship between the head and the loudspeaker was maintained. The microphones in the head were also in this case connected over cathode followers, microphone amplifiers and filters to a level recorder. The tests were carried out in the following way. The head was adjusted in the desired position relative to the loudspeaker, i.e. so that the signal from the loudspeaker reached the head with the azimuth to be investigated. The loudspeaker was then set behind the 10° scale mark and the loudspeaker head system was then rotated so that the loudspeaker was moved along the graduated scale from the 10° mark to the 130° mark. While the system was rotating the intensity was recorded continuously through the head microphones. Since the azimuth and the signal from the loudspeaker are constant during a measurement it is only the acoustics of the room that

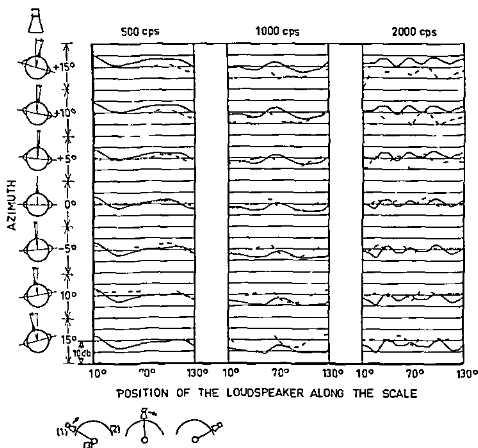


Fig 8

Figs 8–9 Variations in intensity (ordinate) in both the right (dashed) and left (solid lines) ear on the artificial head as a function of the position of the loudspeaker (abscissa) along the graduated scale The tests were carried out at the 500 1000 2000 4000 and 8000 cps frequencies and with white noise The azimuth was altered in 5 steps from 0 to 15 both clockwise and counter clockwise (1) Loudspeaker (2) graduated scale (3) artificial head fitted on the vertical motor shaft

can vary the intensity recorded by the built in microphones It is thus possible to study the variation of intensity at the eardrums as a function of the loud speaker position along the scale for determined azimuths and frequencies In all cases the intensity figures from both the left and right ears were measured The results of these measurements are shown in Figs 8 9 It is thus shown that the position of the loudspeaker along the scale influences both the relative intensity at the ears and the interaural intensity difference

Angular localization by interaural intensity difference

The physical basis of angular localization at frequencies above 1400 cps is the interaural intensity difference (see above) In this study the frequencies concerned are 2000 4000 and 8000 cps Fig 9 shows that the 4000 and

An artificial head of standard size with microphones fitted in the place of the eardrums (Idén & Nordlund 1962) was set up in the centre of the graduated scale, i.e. the place where the head of the subject was to be. The microphones in the head of the model were connected over cathode followers, microphone amplifiers and filters to a level recorder. This made possible continuous recording of the intensity at the location of the eardrums for different signals from the loudspeaker along the scale. Since the head was fitted on a vertical motor shaft, it could be rotated in both directions at a constant speed, so that the angle of incidence (azimuth) of the signal at the head model varied. Turning was then carried out at the same time as the intensity was recorded and in this way the variation of intensity at the eardrums was obtained as a function of azimuth. This intensity function was examined at the frequencies 500, 1000, 2000, 4000 and 8000 cps. Tests were carried out with the loudspeaker at four different positions along the scale in order to see whether this had any influence on the result. The positions of the loudspeaker were behind the scale marks 10°, 50°, 90° and 130°, which were selected as representative points. The head model was rotated both clockwise and counterclockwise from 0° to 180°. The results obtained are illustrated in Figs. 3–7. These show the relative intensity in the ears as a function of azimuth at four different positions of the loudspeaker. It can be seen that the curves for the same frequency have a similar form independent of the position of the loudspeaker. There are, however, variations between measurements carried out for various loudspeaker positions, and these are most obvious at the frequency 8000 cps. This means that there has been a change in the loudspeaker sound field depending on the fact that it has been moved to different positions along the scale. In order to make a closer examination as to whether the modified sound field is dependent on the position of the loudspeaker, the following tests were carried out.

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mainly the interaural phase difference which makes possible the localization of frequencies below 1400 cps It is however possible that the intensity difference contributes to the ability to carry out angular localization also at the 500 and 1000 cps frequencies But since the intensity at the 500 cps frequency varies very slowly as a function of the azimuth (Fig 3) the intensity factor cannot form any basis for the accurate angular localization at this frequency (see Results) At the 1000 cps frequency on the other hand the intensity difference varies more rapidly as a function of the azimuth as shown in Fig 4 The intensity factor can therefore have a certain significance for the localization of this frequency

Angular localization by interaural phase difference

At frequencies of 500 and 1000 cps the interaural phase difference is the most important factor involved in the localization ability It is therefore interesting to see how the phase is influenced by different positions of the loudspeaker along the scale The microphones in the head model were therefore connected across cathode followers to a dual beam oscilloscope so that the phase relationship between the right and left ears could be studied The head loudspeaker system was used in the same way as in the previous tests, i e the head was fitted on the vertical motor shaft to which the movable loudspeaker was connected The nose on the head model was directed at the loudspeaker so that azimuth was 0° and the interaural phase relationship was studied for different positions of the loudspeaker along the scale At the 500 cps frequency it was found that the interaural time difference was so small as to be unmeasurable i e less than ±0 02 msec when the loudspeaker was between the scale marks 10°–70° at 75° a measurable error started to occur and this had increased to 0 05 msec (−9°) at the scale mark 80° This decreased again so that at 90° it was hardly measurable and between the graduations 95°–130° it was unmeasurable This time difference which occurred depending on a sound field modification from the loudspeaker when moved along the scale reached a maximum of 0 05 msec which corresponds to a margin of error from a sound localization viewpoint of less than 5° azimuth (Nordlund 1961) Since this measurable error only occurred within a small range of the scale and several determinations were used for localization tests the average physical error from a sound localization viewpoint will be ±2 5° azimuth

As far as the 1000 cps frequency was concerned Fig 10 shows how the interaural phase relationship varied as a function of the position of the loudspeaker along the scale at an azimuth of 0° This shows that the maximum time difference at 0° azimuth reaches 0 08 msec which corresponds to an angle of error of less than 8° azimuth The average physical error has been calculated to be ±2 7° azimuth on conditions that several determinations are carried out and that these are evenly divided along the scale There is thus a good physical background for the localization of the 500 and 1000 cps frequencies with the help of the interaural phase difference Since interaural

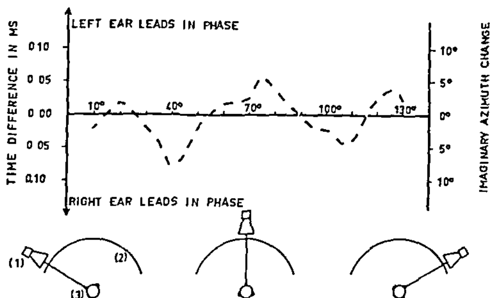


Fig. 10. Investigation of the interaural time difference (ordinate) on the artificial head at a frequency of 1000 cps as a function of the position of the loudspeaker behind the scale (abscissa), where the head is fitted so that the loudspeaker is right in front of it the whole time, i.e. the nose points straight at the loudspeaker. (1) Loudspeaker, (2) graduated scale, (3) artificial head fitted on the vertical motor shaft. "Imaginary azimuth change" is the lateral displacement of the sound source experienced by a person due to the phase displacement occurring between the ears at the various loudspeaker positions.

phase difference cannot be discerned at frequencies above 1400 cps, then phase difference has no significance at the higher frequencies, i.e. 2000, 4000 and 8000 cps.

Angular localization by interaural time difference

Low pass filtered white noise is mainly localized by the aid of the interaural time factor (Christian & Röser 1957). The time difference could not be measured in the case of white noise and therefore the physical prerequisites for the angular localization of this signal could not be determined.

By way of summary the following can be said concerning the physical background for the localization of the various frequencies and low pass filtered white noise by using this method.

The 500 cps frequency, where the phase difference is decisive, is physically possible to localize with an average accuracy of ±2.5°.

At 1000 cps, where both the phase and intensity factors are of significance, it is physically possible to localize with an average accuracy of ±2.7° due to the phase and approximately ±1.5° due to the intensity. In the poorest cases a physical error of ±17.7° can thus occur.

As far as the 4000 and 8000 cps frequencies are concerned, where only intensity relationship is of significance, the physical background for localization gives an accuracy better than ±5°.

Table 1. *Distortion (D_2 and D_3, the second and third overtone respectively) at the different frequencies (F) with intensities of 80 and 70 db (relative 0.0002 dynes/cm²)*

F	db	D_2 %	D_3 %
500	80	1.6	2.5
	70	1.2	1.4
1000	80	1.8	1.3
	70	0.8	0.3
2000	80	0.3	0.3
	70	0.3	0.3
4000	80	0.4	0.3
	70	0.3	0.3
8000	80	0.1	—
	70	0.3	

The background at 2000 cps, where intensity also alone is of significance, has however only a possible accuracy of approximately ±15°.

The physical possibility for the localization of low pass filtered white noise could not be determined.

Distortion was measured by means of a condenser microphone, a microphone amplifier and a ⅓ octave filter. The results of the measurements are shown in Table 1. These results show that the second (D_2) and third (D_3) overtones for frequencies of 2000, 4000 and 8000 cps are of such a magnitude that they cannot normally be discerned by the human ear. This means that distortion cannot influence localization ability at these frequencies. In pathological cases, on the other hand, where the hearing is so defective that the threshold for D_2 and D_3 is considerably lower than for the frequencies considered, there is a risk of the overtones being heard. This must, however, be evaluated from case to case. Distortion at the 500 and 1000 cps frequencies is of such a magnitude that it could possibly be discerned at the strongest intensities. This cannot, however, exert any misleading influence on directional audiometry since these frequencies can be localized equally well for all intensities used (see Results). This means that the second and third overtones do not from a practical point of view contribute to better directional hearing.

There is no audible click at the beginning or end of the signal tone which can result in improved localization of the tones.

Further tests were carried out with a condenser microphone fitted on the motor shaft where the head model was earlier located. The condenser microphone and the loudspeaker thus formed a fixed system relative to each other. The system was then rotated so that the loudspeaker moved along the scale and at the same time the intensity was recorded through the microphone. The signal from the loudspeaker remained constant while measurements were carried out and it was thus only the acoustics of the room that influenced the intensity recorded. The results (Table 2) show the variations of the

TABLE 2 *The limits for the variation in intensity occurring in the centre of the graduated scale when the loudspeaker is moved along the scale*

500	1000	2000	4000	8000
±2.5 db	±4.0 db	±2.0 db	±1.5 db	±1.8 db

intensity depending on the position of the loudspeaker at variable frequencies. These variations are small compared with the intensity range used and will therefore not influence the results.

The position of the loudspeaker along the scale could be read off with an accuracy that was better than ±½°, this being quite sufficient with respect to other sources of error. The subject has excellent possibilities to indicate the direction of the sound source by means of the graduation marks which correspond to the direction experienced. The scale has 2 cm high black figures on a white background. All the graduations are marked to avoid the subject from being tempted to round off the figure in question, for example to the nearest ten.

The loudspeaker is fitted behind a very thin curtain which does not influence the sound field at all but prevents the subject from seeing the loudspeaker. The only way he can judge the position of the loudspeaker is by the signal coming from it.

TESTS CARRIED OUT

In a series consisting of eight persons with normal hearing between 20 and 30 years of age, 130 determinations were carried out on each subject with combinations of different frequencies and intensities. The frequencies used were *500, 1000, 2000, 4000* and *8000* cps. The intensities varied between 20 db and 80 db (relative 0.0002 dynes/cm²) in steps of 10 db. Low pass filtered white noise was also used as a sound source but only, however, at the

TABLE 3

QA = 1 824 9748	V(A) = 361 9919	*FA R* = 1 8911
QB = 5 511 6333	V(B) = 137[illegible] 9082	*FB R* = [illegible] 139[illegible]
QAB = 5 504 5669	V(AB) = 275 2283	*FAB R* = 1 4260
QR = 1[illegible] 369 7500	V(R) = 192.9971	
QT 30 210 9250		
*n*A 06 *n*B 05 *r* = 01		
Df for R 90 AB 20 B 04 A 05		

A intensity B frequency R error AB interaction

The table shows that the variance due to intensity does not differ from the residual variance. The variance due to frequency is significantly greater than the residual variance. Similar results were obtained for each subject. For further information see *Statistiska metoder* H. Hyrenius 19[illegible] Gumperts förlag.

intensities 20 and 60 db The frequencies and intensities used were taken in random order to avoid any partiality towards certain frequencies or intensi ties The results were subjected to an analysis of variance for each subject as shown in Table 3 for one of the subjects

RESULTS

(1) The ability to localize pure tones and low pass filtered white noise was found to be independent of intensity over the range used in these experiments for all the subjects

(2) The ability to localize low pass filtered white noise was significantly better than that for pure tones and the standard deviation about the position of the loudspeaker was ±2 3°

(3) The ability to localize 500 cps was significantly better than that for the other frequencies The ability to localize 1000 cps was significantly better than for 2000 4000 and 8000 cps No significant differences in the accuracy of localization could be detected among the three last mentioned frequencies 2000 4000 and 8000 cps The standard deviation about the position of the loudspeaker for the various frequencies is shown in Table 4

TABLE 4 *Standard deviation about the position of the loudspeaker for the various fre quencies and white noise*

White noise	500 cps	1000 cps	2000 cps	4000 cps	8000 cps
±2 3°	±5 3	+7 2	+10 3°	±8 8	+11 5

(4) Angular localization ability based on interaural intensity differences is poorer than directional hearing based on interaural phase differences

(5) The subject often located the sound source systematically to the right or to the left of the actual position of the loudspeaker The average position relative to the actual position of the loudspeaker given by the subject is called target mark in the following The spread around the target mark is called the target pattern

DISCUSSION

Table 4 shows that the 500 and 1000 cps frequencies are localized more accurately than the higher 2000 4000 and 8000 cps frequencies This implies that an interaural phase difference provides a better guidance for directional hearing than intensity difference This is also the case when the physical error is considered for the different frequencies

Low pass filtered white noise is localized with the greatest accuracy However it is not possible to say that the time difference offers the best basis for angular localization since intensity difference also can contribute in localizing

low pass filtered white noise. It has, however, been shown by Christian & Röser (1957) that directional hearing of white noise is mainly based on time difference discrimination. The ability to localize this stimulus will therefore constitute a measure of the discrimination of an interaural time difference.

The tests carried out did not show any significant difference in the ability to localize at 2000, 4000 and 8000 cps although directional hearing appeared to be most accurate at the frequency of 4000 cps. This can be explained hypothetically by the fact that at the frequency of 2000 cps the physical accuracy is poorer than it is at 4000 cps, while at 8000 cps the great intensity variations in the ear directed away from the sound source (Fig. 7) create confusion so that the subject does not know which way to turn his head.

CLINICAL DIRECTIONAL AUDIOMETRY

On the basis of the tests described above, the basic features of a clinical localization test procedure have been planned as follows.

The tests are to be carried out in the same way as that described above, i.e. the same equipment is to be used with the subject located in the anechoic room and the experimenter in the control room. The task of the subject is the same as described above, i.e. to indicate by stating a figure the direction from which he is experiencing the signal given. The experimenter moves and reads off the position of the movable loudspeaker and notes the direction stated by the subject so that the error can be determined. The following signals are to be used: tones of 500, 2000 and 4000 cps as well as low pass filtered white noise. The intensity is set to a comfortable level for the patient in question. The intensity must not, however, be so low that the signal is not discerned by the worse ear. The patient is then to carry out 20 direction determinations at the 500, 2000 and 4000 cps frequencies and 10 determinations for the low pass filtered white noise. The patient moves his head to localize the sound. The target mark and the target pattern (see above) for the various signals are then calculated. The ability to localize the 500 cps frequency constitutes a measure of the discrimination of an interaural phase difference. The interaural intensity difference is, as previously mentioned, negligible.

The ability to localize the 2000 and 4000 cps frequencies constitutes a measure of the discrimination of an interaural intensity difference. An interaural phase difference cannot be discerned at these frequencies, as stated above.

The ability to localize low pass filtered white noise constitutes a measure of the discrimination of an interaural time difference, as stated above.

In another test series the head of the patient is fixed in order to determine the ability to localize a sound at the sides of the median plane. Otherwise the same procedure described above is used but only low pass filtered white noise is used as a signal and the loudspeaker is not moved more than 30° laterally from the median plane. This test series provides a measure of the patient to determine an interaural time difference.

The method provides a picture of the different functions in angular localization so that an impaired discrimination of interaural time phase or intensity differences can be revealed The method is being tested presently on various types of hearing defects in order to determine the value of directional audiometry as an aid to the topical diagnosis of impaired hearing The results of this work will be described in a later paper

ZUSAMMENFASSUNG

Das Ziel der Versuchsreihe war ein Verfahren für richtungsbezogene Audiometrie zu entwickeln mit dessen Hilfe die verschiedenen Gehörfunktionen bei der Feststellung des Herkunftwinkels des Schalles getestet werden können Das Verfahren hat folgende Eigenschaften

1 Das was wir physiologisches Richtungsgehör genannt haben d h die Fähigkeit zur Feststellung des Herkunftwinkels des Schalles in einem freien Feld kann abgeschätzt werden

2 Mangelnde Fähigkeit bei der Unterscheidung interauraler Zeit Phasen und Tonstärkeunterschiede kann im Einzelfall festgestellt werden Die Fehlerquellen des Verfahrens werden mit Hilfe eines künstlichen Kopfes sorgfältig untersucht

In der Zukunft wird dieses Verfahren richtungsbezogener Audiometrie klinisch überprüft werden damit ermessen werden kann welchen Wert die Untersuchung der Richtungshörfähigkeit bei der topischen Diagnose von Gehörfehlern haben kann

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SOME ASPECTS OF DIRECTIONAL HEARING FILM

BERTIL NORDLUND

This film relates to the papers on Physical Factors in Angular Localization' (Vol 54 1) and 'Angular Localization' (this issue), and may be borrowed on application to Dr B Nordlund, Sahlgrenska Hospital, Gothenburg It is a 16 mm colour film with magnetic sound, and runs for 23 minutes

The first part of the film demonstrates the physical factors in stereophonic hearing These factors are studied by the aid of an artificial head with condenser microphones mounted at the site of the eardrums The microphones are connected to a dual beam oscilloscope and the acoustic stimuli at the eardrums is demonstrated at different azimuths The interaural time and intensity differences with varied types of sounds are thus demonstrated and the physical background of the ability to localize a sound source is discussed

In the second part of the film a method of directional audiometry is demonstrated The method has the following properties

(1) What we have called physiological directional hearing , i e the capacity for angular localization of a sound source in a free field, can be estimated

(2) *Defects in the ability to utilize interaural time phase and intensity* differences as clues to directional hearing can be detected individually by using different types of signals This method of directional audiometry is at present tested clinically in order to estimate the value angular localization may have in the topical diagnosis of hearing defects

The film is very instructive and of good quality It is recommended for tutorial purposes to audiologists hearing therapists and audiometricians

Bengt Barr

DIE MANDIBULÄRE PROTRUSION

Bericht über ein Operationsmaterial

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Bei Fällen mit mandibulärer Protrusion sind die Eigenschaften des Schädels untersucht worden, die die Progenie ausmachen. Die extraorale Osteotomie nach Babcock-Lindemann wurde am freipräparierten Ramus mandibulae ausgeführt. Eine plangemäße Heilung in exakter Lage geschah in ca. 15 % der Fälle. Bei den übrigen Fällen verursachte die Operation eine manchmal bedeutende Deformierung des Ramus mandibulae. Dessenungeachtet erhielt man in der Mehrzahl der Fälle ein sowohl funktionell wie ästhetisch zufriedenstellendes Resultat.

KAP. I

Während der Jahre 1944–1956 wurde in Zusammenarbeit zwischen der Hals-Nasen-Ohrenklinik und der Zentralzahnpoliklinik des Zentralkrankenhauses in Umeå die Korrektion der mandibulären Protrusion bei 91 Fällen ausgeführt.

Materialrapport

Das Material bestand hauptsächlich aus Fällen mit „idiopathischer oder primärer Protrusion", und nur bei 2 Fällen lag eine „sekundäre Protrusion" vor, die durch eine Gaumenspalte bedingt war (Perthes u. Borchers 1932).

Eine Prominenz des Unterkiefers ist in einem Drittel der Fälle auch bei Verwandten beobachtet worden. Man kann daher annehmen, daß hereditäre Faktoren von entscheidender Bedeutung für das Aufkommen der „primären Protrusion" sind. Vergleiche Lundströms Beobachtungen bei der Untersuchung von eineiigen Zwillingen (1948).

Geschlechts- und Altersverteilung

Geht aus der Tabelle 1 hervor.

Kraniometrische Bestimmungen am Röntgenprofil

Da das Material zum größten Teil aus einem geographisch recht begrenzten Gebiet (Provinz Västerbotten) stammte, war es von Interesse, vergleichende Untersuchungen an einem „Normalmaterial" desselben Gebietes auszuführen. Bei der Auswahl dieses Materials hat man prinzipiell Personen mit gut erhaltenem Biß und relativ

TABELLE 1 *Die Geschlechts und Altersverteilung des Progeniematerials*

Geschlecht	Alter bei der Operation 17 19 J	20–29 J	30–39 J	Total ziffer	Prozent ziffer
Frauen	10	20	4	34	37 %
Männer	10	40	7	57	63 %

normaler Okklusion bevorzugt Das „Normalmaterial umfaßte 35 Männer und 35 Frauen Mit Hilfe der erhaltenen Durchschnittswerte machte man Diagrammkonstruktionen für Männer sowie für Frauen (Abb 1 u 2)

Auf Grund des Fokusabstandes in Lysholms Schädelröntgenapparatur (70 cm) erhält man eine Vergrößerung und eine Doppelkonturierung im Röntgenbild Bei den kraniometrischen Berechnungen am Profilbild halbierte man daher den Abstand zwischen den entsprechenden Punkten der rechten und linken Schädelkonturen, und die linearen wie die angularen Messungen geschahen in Übereinstimmung damit (Vgl das entsprechende Verfahren bei Björk, 1947)

Bei nicht zahntragendem Kiefer verwendete man als dem Infradentale entsprechenden „reference point den rechtwinkligen Schnittpunkt zwischen der Tangente, die durch die prominentesten Punkte des Unterkiefers verläuft und einer durch den höchsten Punkt des Alveolarfortsatzes gelegten Linie Der rechtwinklige Schnittpunkt einer durch das Nasale gelegten Linie mit derjenigen, die durch den prominentesten Punkt des Alveolarfortsatzes verläuft, stellt den Bezugspunkt für das Prosthion dar (16 Fälle)

Die Diagramme zeigen die Eigenschaften am Schädel auf, welche, in einzelnen Fällen sehr variierend, die mandibulare Protrusion ausmachen, nämlich die verkürzte (vertikale) Schädelbasislänge (Nasion–Mittelpunkt der Sella turcica), den verkleinerten Schädelbasiswinkel bei der Sella, den verkleinerten Winkel am Kiefergelenk und die Verlängerung des Corpus mandibulae im Profil

Die Durchschnittswerte für die verschiedenen kraniometrischen Faktoren weichen nur in begrenztem Ausmaß von denen anderer veröffentlichter Arbeiten ähnlichen Inhalts ab

TABELLE 2 *Durchsnittswerte und Standarddeviation des „Oberkieferabstandes und des „Unterkieferabstandes des Normalmaterials b w des Progeniematerials*

	Normal material (mm)	Progenie material (mm)
Oberkieferabstand		
Männer	108 ± 5 5	101 ± 6 3
Frauen	102 ± 4 6	97 ± 6 7
Unterkieferabstand		
Männer	114 ± 5 3	122 ± 7 0
Frauen	106 ± 5 3	155 ± 7 3

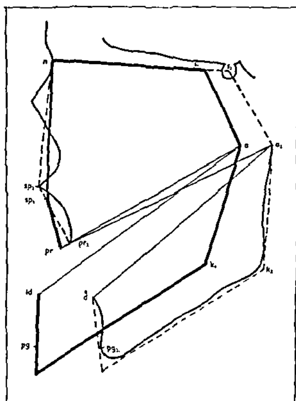


Abb. 1. Männlich. Diagramm der Durchschnittswerte von Röntgenprofilen der Männer ——— Progeniematerial – – – „Normalmaterial". Maßstab 1:2. n Nasion. a_1, a_2 Articulare. s_1, s_2 Zentrum der Sella turcica. k_1, k_2 „Kieferwinkelpunkt". id_1, id_2 Infradentale. pg_1, pg_2 Progonion. pr_1, pr_2 Prosthion. sp_1, sp_2 Spinapunkt.

Den Grad der Protrusion, ohne Rücksicht auf die Zahnstellung, erhält man durch Vergleich der Abstände vom Gelenkkopf, hier gleichbedeutend mit dem Schnittpunkt zwischen dem Schädelbasisprofil und dem hinteren Rand des Kondyls, zum Prosthion bzw. Infradentale (Abb. 1 u. 2), die „Oberkiefer- und Unterkieferabstände" (Tab. 2).

Beurteilung des Progeniematerials

Außerhalb der Grenze des Normalmaterials $M - 2\sigma$ für den Oberkieferabstand (= zu kurzer Oberkieferabstand) fallen 25 % von den männlichen Patienten und 30 % von den weiblichen.

Außerhalb der Grenze des Normalmaterials $M + 2\sigma$ für den Unterkieferabstand (= zu langer Unterkieferabstand) fallen 36,5 % der männlichen Patienten und 50 % der weiblichen.

Das gleichzeitige Vorkommen von zu kurzem Oberkieferabstand und zu langem Unterkieferabstand fand man bei 4 % der Männer und bei 0 % der Frauen.

Aus den Messungen geht hervor, daß die Ursache ausgesprochener Progenie öfter ein zu langer Unterkieferabstand als ein zu kurzer Oberkieferabstand ist.

Anzeigestellung für die Operation

Bei einer verhältnismäßig großen Anzahl von Fällen machten Abbeiß- und Kauschwierigkeiten die Operationsindikation aus. Die meisten dieser in der

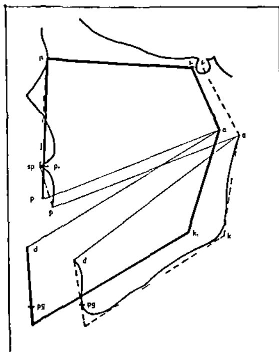


Abb 2 Weibl ch Diagram n der Durchschnittswerte von Röntgenprofilen der Frauen ——— Progeniematerial - - - - Normalmaterial Maßstab 1 2

Regel avancierten Falle von Protrusion wurden von Militarverbanden uber wiesen (18 %) Gewohnlich waren doch asthetische und psychologische Faktoren der Anlaß zur Operation

Die praeoperative Behandlung und Planung

Die Registrierung der Bißstellung und Gelenkbahnen sowie die Artikulator analyse wurden gemacht und an Hand dessen wurden die fur den erwunsch ten postoperativen Biß notwendigen Korrektionen ausgefuhrt (Zahnextrak tionen Bißeinschleifungen und Bruckenkonstruktionen)

Um eine moglichst zufriedenstellende postoperative Okklusion zu erhalten bestimmte man die erwunschte Neigung der Sagerflache im Artikulator und an den Rontgenbildern in der Absicht eine Erhohung bzw eine Senkung des Molargebiets vorzubereiten Eine Sanierung der Zahne und die Behand lung von entzundetem Zahnfleisch wurden konsequent durchgefuhrt

Bei zahntragenden Fallen hat man Drahtbugel zur intermaxillaren Fixa tion appliziert Beim Fehlen von Praemolaren mußten Bißklotze diese er setzen Eine Beißplatte wurde auch in der Absicht verwendet die Fixa tion zu verbessern und eine Aufwartsbewegung der Anguluspartien zu ver hindern

Bei zahnlosen Fallen wurden die Beißschablonen an den Alveolarfortsatz des Oberkiefers mit Stahldrahtligaturen fixiert und am Unterkiefer wurden

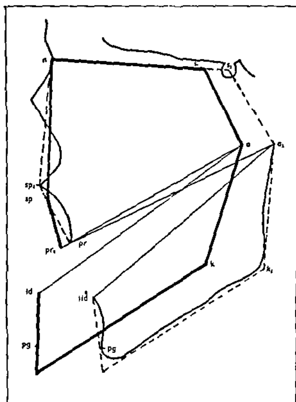


Abb 1 Männlich Diagramm der Durchschnittswerte von Röntgenprofilen der Männer ———, Progeniematerial – ––––, „Normalmaterial Maßstab 1 2 n Nasion a_1, a_2 Articulare s_1 s_2 Zentrum der Sella turcica k_1, k_2 „Kieferwinkelpunkt id_1, id_2 Infradentale pg_1, pg_2 Progonion pr_1 pr_2 Prosthion sp_1 sp_2 Spinapunkt

Den Grad der Protrusion, ohne Rücksicht auf die Zahnstellung, erhält man durch Vergleich der Abstände vom Gelenkkopf, hier gleichbedeutend mit dem Schnittpunkt zwischen dem Schädelbasisprofil und dem hinteren Rand des Kondyls, zum Prosthion bzw Infradentale (Abb 1 u 2), die „Oberkiefer und Unterkieferabstände (Tab 2)

Beurteilung des Progeniematerials

Außerhalb der Grenze des Normalmaterials M – 2 δ für den Oberkieferabstand (zu kurzer Oberkieferabstand) fallen 25 % von den männlichen Patienten und 30 % von den weiblichen

Außerhalb der Grenze des Normalmaterials M +2 δ für den Unterkieferabstand (zu langer Unterkieferabstand) fallen 36,5 % der männlichen Patienten und 50 % der weiblichen

Das gleichzeitige Vorkommen von zu kurzem Oberkieferabstand und zu langem Unterkieferabstand fand man bei 4 % der Männer und bei 0 % der Frauen

Aus den Messungen geht hervor, daß die Ursache ausgesprochener Progenie öfter ein zu langer Unterkieferabstand als ein zu kurzer Oberkieferabstand ist

Anzeigestellung für die Operation

Bei einer verhältnismäßig großen Anzahl von Fällen machten Abbeiß und Kauschwierigkeiten die Operationsindikation aus Die meisten dieser in der

einen Finger im Mund hielt zur Kontrolle der Sagespitze Die Verfasser fanden es am zweckmassigsten die Durchsägung erst an der vorderen Kante durchzufuhren und strebten danach den Knochen bis zur vollstandigen Teilung durchzusägen Dadurch wurde die Aufhangung an Knochenspitzen vermieden was bei der Sprengung von restierenden Knochenbrucken mit dem Meißel vorgekommen ist — Nach großeren Verlagerungen des unteren Fragmentes entfernte man die untere hintere Ecke der Sageflache um einen Druck gegen den Processus mastoideus beim Mundaufmachen zu vermeiden — In einzelnen Fallen machte man eine Osteosynthese mit Hilfe einzelner Stahldrahtligaturen durch die hinteren Teile der Fragmente was doch ohne Bedeutung fur die Fixation war Die Aufwartsbewegung des oberen Fragmentes die oftmals nach der Operation erfolgt konnte man auf diese Weise nicht verhindern Nach der Naht der Parotiskapsel mit Katgut wurden die Hautkanten primar mit Seide genaht

Nach Abschluß der doppelseitigen Operation konnte die Anpassung an die neue Bißlage ohne Schwierigkeiten geschehen Die intermaxillare Fixation wurde mit Stahldrahtligaturen und Gummizugen in den Fallen ausgefuhrt wo man eine zufriedenstellende Okklusion nicht unmittelbar erhielt Ein Kinnverband (Kieferschleuder) und die Aufhangung in einem Capistrum von Papier vervollstandigte die ubrige Fixation Der Verband verleiht dem Patienten ein gewisses Sicherheitsgefuhl aber durfte ohne Bedeutung fur die Fixation sein Die Fixationszeit variierte zwischen 8 und 10 Wochen Bei breitem Kontakt zwischen den Sageflachen der Ideallage und bei zufriedenstellendem und unverandertem Kontakt kam eine kurzere Fixationszeit vor Bei Ein-Punkt Kontakt durch Aufwartsbewegung des oberen Fragmentes wurde die Fixationszeit verlangert Allgemein kann man sagen daß mit einer zufriedenstellenden Konsolidierung fruhestens nach 8 Wochen zu rechnen ist

Nachdem die intermaxillare Fixation entfernt worden war nahm man eine neue Bißeinschleifung und wenn erforderlich eine prothetische Rehabilitierung vor

Wenn die Kinnspitze trotz der Progeniekorrektion allzu hervorstehend war wurde das Aussehen durch eine Resektion derselben verbessert (2 Falle)

Vorubergehende Operationskomplikationen

Komplikationen in unmittelbarem Anschluß an die Operation waren nicht zahlreich Erbrechen und Atemschwierigkeiten kamen nicht vor Mit diesem Risiko mußte doch gerechnet werden und entsprechende Bereitschaftsmaßnahmen gehorten zur Routine Hamatome kamen in 2 Fallen vor ohne Anlaß zum Eingreifen zu geben Die Wundheilung geschah in der Regel p p aber in 3 Fallen verzogerte eine Speichelfistel die Heilung In einem Fall entstand unter der Operationsnarbe eine Speichelzyste Nach Auskratzen und Touchierung mit Lapis geschah die Heilung ohne Rezidiv Temporare Facialisparesen wurden in 10 Fallen beobachtet

Bestehende Operationskomplikationen

In Übereinstimmung mit anderen Verfassern wurde eine relativ große Anzahl von Schädigungen an den Nn. alveolar. inf. gesetzt mit Anästhesie der Kinnregion und der Unterlippe als Folge, in 3 Fällen doppelseitig, in 10 Fällen einseitig, also in ca. 15 % der Fälle. — Bestehende Facialisparesen kamen nicht vor.

In einem Fall wurde ein auriculotemporales Syndrom (Freys Syndrom) beobachtet, welches also Vasodilatation und Transpiration im Hautgebiet vor dem Ohr zeigt bei Reizung zur Salivation. Es gibt Erklärungen dieses Syndroms, und eine besagt, daß dies die Folge einer Reinnervation der Schweißdrüsen durch parasympathische, speichelsekretorische Nerven ist (Gardner, W. u. McCubbin, 1956, Hogeman, 1951, Laage-Hellman, 1957). Der betreffende Patient zeigt immernoch, nach 10 Jahren, ein unverändertes Syndrom (Abb. 4).

Das Verhalten der Unterkieferfragmente nach der Operation

Die Röntgenkontrolle während und unmittelbar nach der Fixationszeit, wenn die Bruchstelle konsolidiert war, wies eine relativ kleine Anzahl von Fällen mit Heilung in „Ideallage" auf, wo eine Parallelverschiebung stattgefunden hatte und ein guter Kontakt zwischen den Fragmenten etabliert wurde. Das obere Fragment hat eine ausgesprochene Tendenz nach vorne und oben zu rotieren, und das untere Corpus–Ramus–Fragment verhält sich dementsprechend. In der Mehrzahl der Fälle war die Aufwärtsbewegung des Kondylfragmentes auf beiden Seiten von gleichem Ausmaß. Diese Situation führte auch eine nicht geplante Verkürzung des Ramus mandibulae mit sich (Abb. 5). Es kam auch in der Frontalebene eine Seitenverschiebung des oberen Fragmentes nach medial vor, was auch eine Verkürzung der Ramuslänge zur Folge hatte. Bemerkenswert war, daß diese nicht gewünschten Fragmentverschiebungen während der Fixationszeit auftraten und von erheblichem Ausmaß waren. Von 54 röntgenologisch zufriedenstellend untersuchten Fällen wiesen 24 einen nach vorn offenen Winkel zwischen den Sägeflächen auf, der zwischen 21° und 45° variierte, was also fast 50 % der Fälle entsprach. Eine gleichzeitige Seitenverschiebung der Fragmente kam in 5 Fällen vor. Wenn eine Winkelstellung zwischen den Bruchflächen von weniger als 20° festgestellt wurde, hatte auch gleichzeitig eine Verschiebung in der Seitenlage stattgefunden. Einen „side to side" Kontakt der Ramusfragmente beobachtete man in 13 von 30 Fällen. Diese unvorteilhaften Dislokationen führten bei den meisten Fällen eine Verkürzung des Kondylkieferwinkelabstandes der „Ramushöhe" von mehr als 10 mm mit sich.

Die Winkel- und Seitenverschiebungen zwischen den Fragmenten und die Verkürzungen der „Ramushöhe" haben eine Heilung nicht verhindert, aber resultierten in Deformierungen des Ramus, die bei Nachkontrollen 2–10 Jahre nach den Operationen noch festgestellt werden konnten. Eine Konso

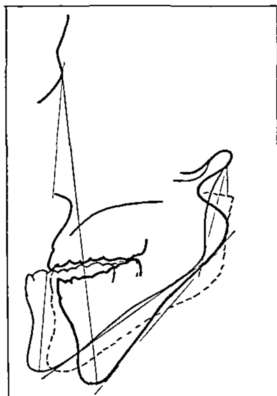


ABB 5 Profilzeichnung der Ramusverkürzung ——— Das präoperative Profil - - - - Die geplante Verlagerung ——— Das postoperative Profil Die Zeichnung zeigt die Fragmentrotation die Gesichtsverlängerung (152 160 mm) und die Verkürzung des Ramus (51 38 mm) Offener Biß

lidierung in der geplanten exakten Lage ist in 8 von den erwähnten 54 Fällen eingetroffen also in 15 % der Fälle

DISKUSSION

Die hier verwendete Operationstechnik wobei also der Ramus mandibulae nach der Freilegung unter direkter Observation abgesägt wird hat nur wenige unmittelbare und bleibende Komplikationen zur Folge gehabt Facialisschaden mit bleibender Paralyse hat man ganz vermeiden können was dagegen bei Operationen ohne Freilegung des Ramus kaum möglich sein dürfte Schaden an den Nn alveol inf waren relativ zahlreich und verursachten *besonders bei Doppelseitigkeit erhebliches* Unbehagen z *B* Verunreinigung des Kinns durch Speise und Speichel ohne daß dies mit dem Gefühl kontrolliert werden konnte (Bei einem späteren Material das 41 Fälle mit mandibulärer Protrusion umfasste ist das Gefäß und Nervenbündel durch einen zu diesem Zweck konstruierten Spatel geschützt worden

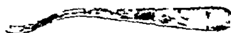


Abb. 6. Der Spatel, welcher auf der Medialseite des Ramus zum Schutz der A. und des N. alveolaris inf. verwendet wird.

(Abb. 6), wodurch die Anzahl von Nervenschäden dieser Art erheblich reduziert wurde (3 von 41 Fällen).)

Die Operations- und Fixationsmethoden haben in den meisten Fällen ein anatomisch zufriedenstellendes Resultat ergeben. In einigen Fällen ist eine bedeutende Deformität entstanden, wobei der Kondyl so gut wie horizontal lag und das Gesichtsprofil ein vogelartiges Aussehen angenommen hatte (Abb. 7 und 8).

Ein besseres anatomisches Resultat ohne Osteosynthesen zu erhalten, dürfte schwer sein. Die Resultate zeigen, daß auch die genaueste Planung und

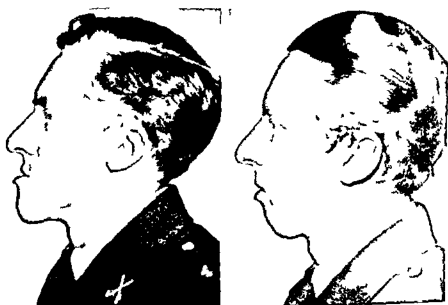


Abb. 7. Fall mit Protrusion, welcher nach der Operation den Charakter eines Vogelgesichtes bekam. I. Vor der Op. II. Nach der Op.



Abb 8 Fall mit Protrusion Cilioschenbiß heilte nach der Operation in der geplanten und korrekten Lage I Vor der Op II Nach der Op

Indizierung der Osteotomie die Lage nicht besser machen Trotz der entstandenen Kieferdeformitäten sind bei der Nachkontrolle die Bißverhältnisse die Kieferartikulation und das Aussehen des Gesichts im Profil und en face im grossen und ganzen befriedigend gewesen (vgl Kap III)

Als Ursache der Aufwärtsbewegung des oberen Fragmentes hat man Kontraktionen des M pterygoideus ext und der vorderen Portion des M temporalis (Dufourmentel 1929) sowie nach angefangener Rotation den Effekt des M pterygoideus internus und des M masseter angenommen

Lundberg *et al* (1957) und Lysell *et al* (1960) haben gezeigt daß die intermaxillare Fixation a liquefaction of the alveolar bone in the apical region and in some cases incipient resorption of the apices of the teeth eine gesteigerte Beweglichkeit und ein partielles Ausziehen der Incisivi mit sich führt wonach eine Aufwärtsbewegung der Angulusspartien möglich wird

In gewissen Fällen mit offenem Biß kann eine Parallelverschiebung zwischen oberem und unterem Fragment unter keinem Umständen eine zufriedenstellende Okklusion ergeben und darum ist in dieser Situation eine Corpusostektomie vorzuziehen (Lysell *et al* 1960)

KAP III

Die Resultate der Bißuntersuchungen 2 10 Jahre nach der Operation

Von dem früheren Material sind 44 Patienten zur odontologischen Nachuntersuchung erschienen Das Zeitintervall zwischen dem Operationsdatum und der Nachuntersuchung variierte zwischen 2 und 10 Jahren

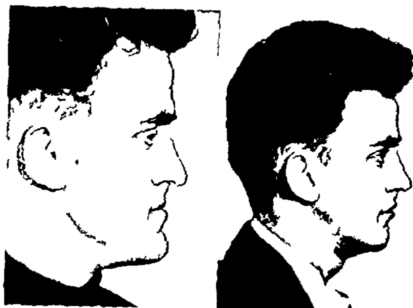


Abb. 9. Fall mit Protrusion. Stahlnaht-Kinnschiene nach der Operation in der geplanten und korrekten Lage. I Vor der Op. II Nach der Op.

Die Methodik der Nachkontrollen umfaßte drei Momente: Bißkontrolle, Röntgenkontrolle (nach Updegrave, Fig. 10) und die klinische Funktionsuntersuchung. Die letztere bestand aus dem klinischen Status der Kiefergelenke und den Messungen der extremen Mundöffnung sowie der Vorwärts- und Seitenbewegungen des Unterkiefers. Die extreme Mundöffnung wurde im Abstand zwischen den Incisivi des Ober- und Unterkiefers mit Hilfe einer dreieckigen Meßscheibe berechnet, die Vorwärts- und Seitenbewegungen des Unterkiefers wurden mit einem Lineal gemessen, wobei man die Abweichung des Unterkiefers von einer Senkrechte feststellte, die durch die Mesialkontakte der Oberkieferschneidezähne verlief. Das Material teilte man in zwei Gruppen ein (nach Hogeman 1951).

Gruppe I (28 Patienten). Patienten mit persistierenden Zähnen und mit relativ befriedigender Okklusion, d. h. 3-Punkt-Kontakt mit Okklusion in der Frontalregion und den Tuberpartien sowie mit Über- oder Kantenbiß der Schneidezähne.

Gruppe II (16 Patienten). Patienten mit prothetischen Konstruktionen, die

TABELLE 3. *Die Verteilung des Materials nach Geschlecht und Alter*

Geschlecht	Alter		
	15–19 J.	20–29 J.	30–39 J.
Frauen	7	15	1
Männer	1	1	5

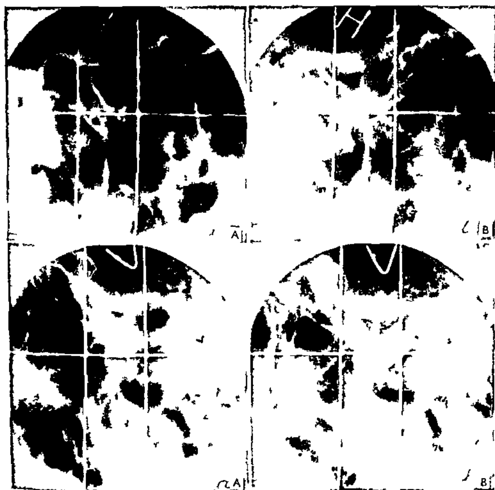


Abb. 10 Röntgenbilder (nach Updegrave) über die Kiefergelenkregionen nach der Operation (*a*) Stellung bei geöffnetem Mund rechte und linke Seite (*b*) Stellung bei geschlossenem Mund rechte und linke Seite

im Zusammenhang mit der Korrektion ausgeführt wurden um den Biß bei defekten Zahnstellungen bzw. bei ganz zahnlosen Kiefern zu rehabilitieren. Zu diesen Fällen wurden auch diejenigen gerechnet, bei denen in der Kontrollzeit Extraktionen ausgeführt und die Zähne durch prothetische Konstruktionen ersetzt wurden.

Resultat

Die folgenden Resultate wurden bei der Nachuntersuchung festgestellt.

Die Bißverhältnisse

Gruppe I. Von den 28 Patienten dieser Gruppe hatten 25 (ca. 90 %) eine zufriedenstellende *Okklusion*, d. h. mindestens 3 Punkte Kontakt. Von den übrigen drei Patienten hatte einer keine Okklusion in den Tuberpartien (Ab

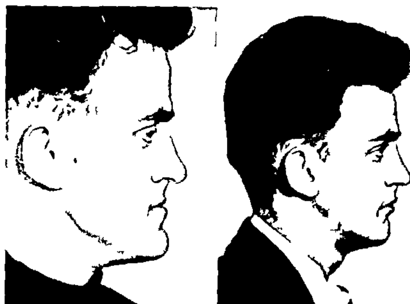


Abb 9 Fall mit Protrusion Stahlmannskinn heilte nach der Operation in der geplanten und korrekten Lage I Vor der Op II Nach der Op

Die Methodik der Nachkontrollen umfaßte drei Momente Bißkontrolle Röntgenkontrolle (nach Updegrave Fig 10) und die klinische Funktionsuntersuchung Die letztere bestand aus dem klinischen Status der Kiefergelenke und den Messungen der extremen Mundöffnung sowie der Vorwärts und Seitenbewegungen des Unterkiefers Die extreme Mundöffnung wurde am Abstand zwischen den Incisivi des Ober und Unterkiefers mit Hilfe einer dreieckigen Meßscheibe berechnet die Vorwärts und Seitenbewegungen des Unterkiefers wurden mit einem Lineal gemessen wobei man die Abweichung des Unterkiefers von einer Senkrechte feststellte die durch die Mesialkontakte der Oberkieferschneidezähne verlief Das Material teilte man in zwei Gruppen ein (nach Hogeman 1951)

Gruppe I (28 Patienten) Patienten mit persistierenden Zähnen und mit relativ befriedigender Okklusion d h 3 Punkte Kontakt mit Okklusion in der Frontalregion und den Tuberpartien sowie mit Über oder Kantenbiß der Schneidezähne

Gruppe II (16 Patienten) Patienten mit prothetischen Konstruktionen die

TABELLE 3 *Die Verteilung des Materials nach Geschlecht und Alter*

Geschlecht	Alter 15 19 J	20–29 J	30 39 J
Frauen	–	15	1
Männer	1	15	5

TABELLE 6 *Abhängigkeit der Rezidivtendenz von verschiedenen Faktoren*

Rezidivtendenz	1 mm	2 mm	3–6 mm
Durchschnittsalter des Patienten bei der Korr	23 4 Jahre	22 8	21 9
Größe der Dorsalverschiebung bei der Korr	7 7 mm	9 0	8 2
Durchschnittliche Fixationszeit nach der Korr	51 4 Tage	53 3	59
Zeitintervall zwischen Korr u Nachkontrolle	5 3 Jahre	4 6	3 9

einen unveränderten Status aufwiesen Bei den übrigen Patienten mit Prothesen konnte man nur schätzungsweise entscheiden ob ein Rezidiv bzw eine Tendenz dazu vorlag Die Bißsenkungen die durch Knochenresorption verschiedenen Grades im Kieferskelett verursacht wurden sind nicht durch neue Prothesen kompensiert worden Mit Hilfe provisorischer Bißerhöhungen konnte man aber feststellen daß die Relation der Kiefer zu einander in sämtlichen Fällen von solcher Art war daß man sowohl aus statischem als auch aus ästhetischem Gesichtspunkt mit neuen Prothesen eine zufriedenstellende Bißrehabilitierung ausführen konnte Die Okklusion in den Fällen, wo die Resorption am wenigsten ausgesprochen war war durchgehend gut

Die Beweglichkeit der Kiefergelenke

Um eine Auffassung von der Beweglichkeit und Funktionsfähigkeit der Kiefergelenke nach der Korrektion zu bekommen hat man Messungen der maximalen Mundöffnung Vorwärts und Seitenbewegungen des Unterkiefers gemäß den früher erwähnten Prinzipien gemacht Das Resultat der Seitenbewegung ist die Durchschnittszahl der Werte bei linkem und rechtem Seitenbiß (Siehe Tabelle 9 S 15) (Die Messungen umfaßten nicht das prothetische Material da völlige Exaktheit nicht erreicht werden konnte)

Störungen in den Kiefergelenken bei Artikulationsbewegungen

Spontane Schmerzen in den Gelenken sind nicht vorgekommen Drei Patienten waren bei Palpation während der Kieferbewegung über einem von den Gelenken druckempfindlich Fünf Patienten hatten Krepitationen und neun Gelenkknacken verschiedener Stärke Nur ein Fall hatte Symptome an beiden Kiefergelenken Von den 44 Patienten die untersucht wurden, zeigten 14 Störungen der Gelenkfunktion in irgendeiner Form

Die Röntgenkontrolle der Lage des Kondyls

(Variationen bei ein und demselben Patienten sind vorgekommen weshalb die angegebene Ziffer einen Durchschnittswert der Messungen der rechten und linken Seite darstellt)

TABELLE 7 *Der Abstand zwischen Tuberculum articulare und dem nächsten Punkt am Kondyl vor und nach der Korrektion*

Abstand (mm)	1	2	3	4	5 7
Vor der Korr	3	26	13	2	0
Nach der Korr	1	8	20	7	8

TABELLE 8 *Der Abstand zwischen dem hinteren Rand der Fossa glenoidalis und dem nächsten Punkt des Kondyls vor und nach der Korrektion*

Abstand (mm)	1	2	3	4
Vor der Korr	1	10	30	3
Nach der Korr	8	30	5	1

Die Messungen zeigen daß der Kondyl im Zusammenhang mit der Korrektion nach hinten in die Gelenkhöhle gepreßt wurde und daß dieser Zustand bestehend geworden war

DISKUSSION

Aus den erhaltenen Werten geht hervor daß eine zufriedenstellende Okklusion durch die ausgeführte Korrektion erzielt wurde und daß man diese Okklusion in den meisten Fällen auch hat beibehalten können Von den 28 zahntragenden Patienten hatten bei einer einfacheren Einschleifung in einem Fall 26 (ca 93 %) zufriedenstellende Okklusion mit mindestens Dreipunktskontakt Was die Patienten betrifft die ganz oder zum größten Teil Zähne vermißten kann man auch feststellen daß es durch die Progeniekorrektion möglich geworden ist den Biß mit Hilfe von prothetischen Konstruktionen zu rehabilitieren die sowohl ästetisch als auch statisch ihre Aufgabe wohl erfüllten Was den Bewegungsumfang des Unterkiefers betrifft scheint eine gewisse Einschränkung entstanden zu sein Keiner von den kontrollierten Fällen hat sich aber darüber beklagt (Tab 9)

TABELLE 9 *Vergleich mit dem von Hogeman veröffentlichten Material im Hinblick auf die Durchschnittswerte für maximale Mundöffnung sowie für die Vorwärts und Seitenbewegungen des Unterkiefers*

Material	Mundöffnung mm	Vorwärts-bewegung	Seitenbewegung
Hogemans klin Material	43 6	7 5	7
Hogemans Kontrollmaterial	4 1	3	8 5
Unser Material	44 3	5 3	0

Störungen irgendwelcher Art über den Kiefergelenken bei Artikulationsbewegungen hatten ca. 32 % des Materials, davon allerdings nur 3 Patienten mit subjektiven Beschwerden in Form von Palpationsschmerz über dem einen Gelenk. Eine gewisse Bedingung für diese Komplikation scheint dadurch entstanden zu sein, daß der Kondyl nach hinten in die Gelenkhöhle gedrängt wurde. Dies kann mit dem kräftigen Cuspschluß erklärt werden, den man beim Einschleifen erstrebt, um einem Rezidiv vorzubeugen. Man hat diese Beschwerden dadurch eliminieren können, daß man etwa ein Jahr nach der Korrektion durch eine erneute Einschleifung den Biß öffnete.

Aus den Messungen geht ebenfalls hervor, daß bis zu einem gewissen Grad ein sagittales Rezidiv entsteht. Dabei findet man die größte Rezidivtendenz bei den Fällen, wo man die größte Zurückschiebung machen mußte. Durch Modellstudien vor und nach der Korrektion bekommt man den Eindruck, daß ein Teil der Rezidive auf der verringerten Inklination der Schneidezähne des Unterkiefers beruht, wahrscheinlich wegen erhöhtem Zungendruck und verringertem Lippendruck in der neuen Lage (vgl. Hogeman 1951).

Die Rezidivtendenz in der Transversalebene scheint bei einer größeren Anzahl von Fällen vorzuliegen. Hierbei ist ein guter Cuspschluß notwendig, wenn der Unterkiefer nicht ganz in seine ursprüngliche Lage zurückgehen soll. Aus diesem Anlaß ist auch eine komplettierende Bißeinschleifung nach einigen Jahren notwendig bei sowohl dem geschlossenen Biß wie bei denen, die durch ein Rezidiv Artikulationsschwierigkeiten verschiedenen Grades bekommen haben. Dabei sollte auch der eventuelle Durchbruch der Weisheitszähne kontrolliert werden, da diese dadurch, daß sie ein Gleithindernis darstellen, einen Teil der Komplikation verursachen können.

Die Zusammenfassung der Bißuntersuchung

Von den 28 Patienten mit eigenen Zähnen hatten 26 oder 93 % zufriedenstellende Okklusion. Bei 16 Patienten mit prothetischem Ersatz war es in sämtlichen Fällen möglich, auf eine statisch und ästhetisch zufriedenstellende Weise den Biß nach der Korrektion zu rehabilitieren. Die Rezidivtendenz war sowohl in der Sagittal- wie in der Transversalebene recht bedeutend. Eine Überkorrektion des Unterkiefers beim Planen des jeweiligen Falles schien daher in der Sagittalebene berechtigt zu sein, ebensowie eine gewisse Restriktion bei der Verlagerung in der Transversalebene. Die Operation sollte vor dem Alter von 20 Jahren vermieden werden.

Reaktionen in den Kiefergelenken konnten bei 14 von 44 Patienten nachgewiesen werden, von denen aber keiner unaufgefordert über subjektive Beschwerden klagte. Als Ursache dieser Gelenkreaktionen kann man die Rückverschiebung des Kondyls in die Gelenkhöhle ansehen.

SUMMARY

A study has been made of the properties of the cranium that constitute mandibular protusion. Extra oral osteotomy by the method of Babcock and Lindemann was per

formed on the exposed mandibular ramus Healing in correct position according to programme was recorded in about 15 per cent of the cases In the other cases the operation resulted in a sometimes marked deformation of the ramus Notwithstanding this, a satisfactory result was obtained in respect of function and aesthetics in the majority of the cases

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INITIAL AUDITORY ADAPTATION

II In Impaired Hearing

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Initial auditory adaptation is the depression of the sensitivity of the ear which is observed immediately after low intensity stimulation and from which recovery is obtained within less than one second after the cessation of the stimulus

Site of Adaptation

No correlate to this reversible threshold shift in man can be found in the cochlear microphonics (Gisselsson & Sorensen 1959) whereas a correlate has been demonstrated in the nerve action potentials (Sorensen 1959)

However the site of initial adaptation is still a matter of discussion

Luscher & Zwislocki (1949) in observation of a patient suffering from hearing loss due to acoustic trauma found an abnormally great adaptation effect measured by means of short tones According to their observation the adaptation areas at high intensities of the stimulus tone tend to reach values of the same order of magnitude as those determined in the normal subject by equal physical intensities of the stimulus they regarded this as an indirect demonstration of the presence of the recruitment phenomenon

According to this adaptation should be localized to the receptor cells

De Maré (1939) in comparing the sensitivity shift of the ear with that of other end organs came to the conclusion that it is due to adaptation of the end organ the time of recovery being of the same order as that of the pressure end organs of the skin

Harris & Rawnsley (1953) also approached the problem in psychoacoustic experiments By the technique of simultaneous binaural loudness balance between a normal ear and one undergoing a threshold shift as a result of a preceding adaptation stimulus it was possible to demonstrate recruitment in the adapted ear whereas it was concluded that the site of the phenomenon of auditory adaptation is the peripheral sense organ

On the other hand according to Hood (1950) and de Maré (1951) the presence of recruitment has not been revealed in the ear during adaptation whereas this phenomenon has been clearly demonstrated in the fatigued ear (Davis *et al* 1950)

[1] Aided by a grant from Fonden til Lægevidenskabens Fremme

Bentzen (1953) stated that adaptation is an adjustment of the perceptive auditory organ, probably localized to the peripheral auditory organ

Langenbeck (1959) expressed the view that the adaptation is localized to the cochlea and probably depends on mechanical alternations in the elasticity of the tectorial membrane or the sensory hairs of the organ of Corti, a possibility which was also suggested by Ranke (1953) and Kietz (1958)

Clinical Application of Adaptation Measurement

In the topical diagnosis of impaired hearing, the most useful tests are bone conduction threshold measurement and binaural loudness balance test, combined with Rinne's and Weber's tests Bone conduction tests are often subject to considerable error, and the binaural balance technique can only be applied in patients with unilateral deafness

If the phenomenon of auditory adaptation is localized to the peripheral auditory end organ (either the hair cells or the nervous tissue) it might possibly give information on the amount of nerve deafness present in, e g otosclerosis Furthermore, the measurement of adaptation might give a monaural determination of the recruitment

Accordingly, it has repeatedly been suggested that measurements of adaptation should be utilized as a clinical routine test, and some authors have studied the behaviour of adaptation in patients with various forms of impaired hearing

By means of short tones, de Mare (1939) studied the post stimulatory threshold shift in 40 patients with perceptive or conductive deafness, or with a combination of both In conductive deafness, he found a post stimulatory effect which was less than in normal subjects, and which decreased with the severity of the deafness In patients with perceptive deafness, the values obtained were of the same order as in normal subjects, or even higher This applied to balance tests, in which the after effect thus seems to follow loudness Measurements of the threshold shift gave essentially the same results In perceptive deafness, the effect was of the same order as in normal subjects stimulated by the same intensity, but whereas the loudness balance tests failed to show any correlation between the severity of deafness and the adaptation the measurements of threshold shifts showed that the effect increased with the deafness In addition, just as in normal subjects, the values of the threshold shifts were, on the whole, lower than those obtained in the balance tests When the primary and secondary tones were presented at a certain interval, the increase in the effect became less pronounced De Mare expressed the view that an increased after effect is due to damage to the sensory cells of the organ of Corti, and suggested that the method may be of value not only in the differentiation between perceptive and conductive deafness, but also in the diagnosis of various types of perceptive deafness

Gardner (1947) applied his short tone auditory fatigue test as a method of obtaining an impairment analysis The frequency space between the

stimulus tone and the test tone was chosen in such a manner that in normal individuals, adaptation was absent below 40 db above threshold A theoretical explanation of this phenomenon was based on the assumption of the existence of an excitatory pattern of the basilar membrane (see Fig 1) If the pattern of the secondary tone should extend above the pattern of the *stimulus tone (due to high intensity), or if it should be situated at a different* position along the basilar membrane (due to different frequency) the subject will be able to hear the secondary tone, even when it is preceded by the stimulus tone In other words, adaptation does not occur until the position amplitude and spread of the primary tone pattern include the pattern of the secondary test tone

Consequently, in conductive deafness, the threshold of adaptation will be as much higher as the conductive loss present, whereas in perceptive deafness, the adaptation occurs at the same intensity level as in normal individuals In this way it might be possible to differentiate between conductive and perceptive deafness and, in cases of mixed deafness, also to assess the amount *of nerve deafness present*

Pirodda & Zwislocki (1952) carried out experiments on a large series of patients with end organ deafness in order to investigate the possibility of clinical application of the adaptation phenomenon They pointed out that the behaviour of adaptation for single frequencies of the test tone depended on the shape of the threshold audiogram the values being only comparable with normal figures in cases of flattened audiometric curves or of localized hearing losses when the frequency of the stimulus tone is situated on the descending side of the audiogram However, by measuring the whole adaptation area in several cases in which the presence of recruitment had been demonstrated by other methods they found that the behaviour of this area corresponds to the behaviour of loudness and thus permits the detection of the recruitment phenomenon This procedure is too complicated and protracted for general clinical use

Personal Investigations

The purpose of the present paper was on the basis of previously published results obtained in normal individuals (Sorensen 1962) to apply an adaptation test in various forms of deafness in order to evaluate the clinical usefulness of adaptation measurement

The method apparatus and procedure of the test were described in detail in the previous paper on the results in normal individuals

The *following measurements were performed*

1 The increase in intensity in db from the actual hearing threshold to incipient adaptation referred to as minimal stimulus intensity (MSI)

2 The size of the adaptation (SA) after a further 20 db increase of the primary tone

At the frequencies 250 1000 and 4000 cps the average values obtained

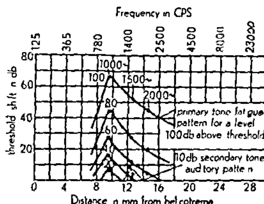


FIG 1 Showing the pattern on the basilar membrane of the test tone and of the stimulation tone at various intensities (From Gardner)

in normal subjects were *MSI, 52 4, 56 0 and 54 0 db, SA, 12 8, 13 0 and 14 0 db*

A total of 192 patients was studied In all cases, a careful clinical history was taken, and the patients were subjected to a general physical and oto logical examination If pathological changes in the tympanic membrane were suspected, otoscopy was supplemented by ear microscopy In addition vestibular tests for spontaneous and positional nystagmus and caloric tests by the method of Fitzgerald Hallpike were performed The hearing was examined by pure tone audiometry with air and bone conduction and by Rinné's and Weber s tests performed by means of a tuning fork and audio meter The patients were studied for recruitment by Fowler s binaural balance test or, when this could not be used, by Reger's monaural test In many cases, the recruitment examination was supplemented by measure ments of the stapedius reflex, which was also used in the assessment of a possible fixation of the stapes Patients with perceptive deafness were also subjected to a thorough neurological examination including electro encepha lography and, in some cases, examination of the spinal fluid, carotid arterio

TABLE 1 *Age distribution of patients with impaired hearing*

	Conductive deafness	Otosclerosis	Labyrinthine deafness	Retrolabyrinthine deafness
<29	10	15	5	7
30 39	4	20	7	4
40–49	4	16	21	5
50 59	3	9	16	8
60–69		1	7	1
70 79	1		1	1
>80			1	
Total	22	61	58	26

graphy and pneumo encephalography Radiographic examination with tomography of the temporal bones was performed in most cases

On the basis of the clinical history and the results of the aforementioned examinations the patients were divided into four groups (Table 1) A fifth group of patients with perceptive deafness in whom the sites of the lesions could not be stated was not subjected to statistical analysis

Conductive deafness

This group consists of 22 patients (eight women and 14 men) with impaired hearing referable to middle ear disease Most of the patients had bilateral chronic suppurative otitis media Chronic catarrhal otitis media was revealed in four and seven had impaired hearing referable to sequelae of otitis media or operation As appears from the histograms (Fig 2) the

TABLE 2 *MSI and SA in conductive deafness*

	Frequency	Age years	Average db	Standard deviation db
MSI	250	≤60	52 9	5 0
	1000	≤60	55 2	7 2
	4000	≤60	[illegible]	5 9
		50–60	46 0	5 9
SA	*250*	*≤60*	*10 8*	
	1000	≤60	9	
	4000	≤60	10 3	

measurements of adaptation showed that incipient adaptation generally occurs at 52 55 db above the actual threshold (see Table 2) In the oldest age group (50 59 years) the average was appreciably lower viz 46 db The dispersion of the measured results was smaller than in the normal series

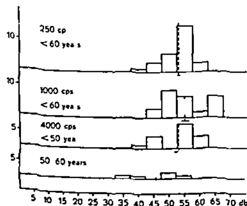


FIG 2 The distribution of MSI in conductive deafness

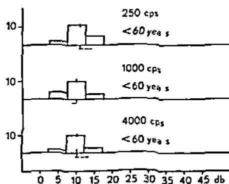


FIG 3 The distribution of SA in conductive deafness

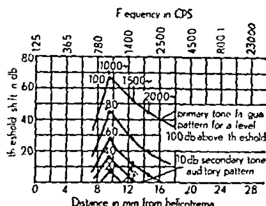


Fig 1 Showing the pattern on the basilar membrane of the test tone and of the stimulation tone at various intensities (From Gardner)

in normal subjects were MSI 52 4, 56 0 and 54 0 db, SA 12 8 13 0 and 14 0 db

A total of 192 patients was studied In all cases, a careful clinical history was taken and the patients were subjected to a general physical and otological examination If pathological changes in the tympanic membrane were suspected otoscopy was supplemented by ear microscopy In addition vestibular tests for spontaneous and positional nystagmus and caloric tests by the method of Fitzgerald Hallpike were performed The hearing was examined by pure tone audiometry with air and bone conduction and by Rinne s and Weber s tests performed by means of a tuning fork and audiometer The patients were studied for recruitment by Fowler s binaural balance test or when this could not be used, by Reger s monaural test In many cases the recruitment examination was supplemented by measurements of the stapedius reflex which was also used in the assessment of a possible fixation of the stapes Patients with perceptive deafness were also subjected to a thorough neurological examination including electro encephalography and in some cases examination of the spinal fluid carotid arterio

Table 1 *Age distribution of patients with impaired hearing*

	Conductive deafness	Otosclerosis	Labyrinthine deafness	Retrolabyrinthine deafness
< 29	10	15	5	7
30 39	4	20	7	4
40–49	4	16	21	5
50–59	3	9	16	8
60–69		1	7	1
70– 9	1		1	1
≥ 80			1	
Total	22	61	58	26

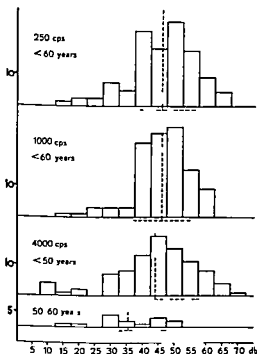


Fig 4 The distribution of MSI in otosclerosis

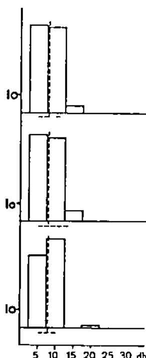


Fig 5 The distribution of SA in otosclerosis

The largest subgroup consists of 38 patients with a diagnosis of Meniere f sease

In addition, there are 10 patients with tumours of the cerebello pontine gle, viz nine cases of neurinoma of the acoustic nerve and one case of trocytoma of the left side of the pons

A subgroup of six patients was recorded under a diagnosis of labyrinthosis, uch corresponds to an atypical Meniere syndrome Congenital impair ent of hearing was present in two, including one in whom it was associated th retinitis pigmentosa One patient is grouped under neurolabyrintho thia toxica, in this case the impaired hearing was referable to sarcoidosis oeck) There was one patient in each of the groups neurolabyrinthopathia ofessionalis and neurolabyrinthopathia traumatica (due to noise trauma) ie subgroup of neurolabyrinthopathia posttraumatica consists of three ses of impaired hearing referable to head injuries Seven cases of impaired aring following infectious diseases were grouped under a diagnosis of urolabyrinthopathia postinfectiosa The infections concerned were in ienza, 3, encephalitis 2 otitis media, 1, meningitis, 1 The subgroup of urolabyrinthopathia vascularis comprises eight patients with perceptive afness which was assumed to be related to vascular disease Four of these tients suffered from cerebral arteriosclerosis two had arterial hyper ision, and two had other vascular disorders Finally, there is a group of

TABLE 4 *All patients grouped according to the presence or absence of recruitment*

Diagnosis	Recruitment	
	Absent	Present
Morbus Ménière		38
Morbus Menière atypica	1	5
Neurolabyrinthopathia congenita	2	
Neurolabyrinthopathia toxica		1
Neurolabyrinthopathia professionalis		1
Neurolabyrinthopathia traumatica		1
Neurolabyrinthopathia posttraumatica	2	1
Neurolabyrinthopathia postinfectiosa	3	4
Neurolabyrinthopathia vascularis	2	6
Neurolabyrinthopathia typus incertus	6	1
Total	16	58
Tumor anguli cerebellopontinus	9	1

seven patients in whom the pathogenesis of the hearing impairment could not be definitely established these are listed under the diagnosis neurolabyrinthopathia typus incertus

All patients with perceptive deafness were examined for the presence of recruitment This examination was performed by means of Fowler's binaural balance test with alternating short tones or in cases with symmetrical hearing loss by Reger's monaural test In a large number of patients the recruitment test was supplemented by recording of the stapedius reflex In Table 4 the patients are grouped according to the presence or absence of recruitment

The hearing loss in all patients without recruitment and in the 10 patients with cerebello pontine tumours are regarded as retrolabyrinthine whereas the hearing loss in the patients with recruitment is considered to be localized in the labyrinth The results of the measurements of adaptation were calculated separately for each of two groups (labyrinthine and retrolabyrinthine) in order to clarify if the test can be used in the topical diagnosis of perceptive deafness

Initial adaptation in labyrinthine deafness

As appears from the histograms (Fig 6) the averages for incipient adaptation (MSI) for patients with labyrinthine deafness were 29.6 29.2 and 22.8 db at the frequencies 250 1000 and 4000 cps respectively (Table 5) these values were significantly lower than those in the normal series The dispersion of the measured results seemed somewhat greater than among the normal subjects but this difference is not statistically significant Just as in the normal subjects the values were found to be lowest at high frequencies

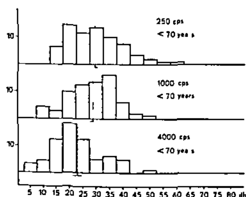


Fig 6 The distribution of MSI in labyrinthine deafness

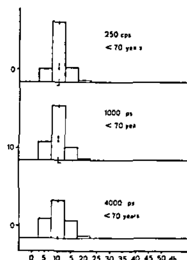


Fig 7 The distribution of SA in labyrinthine deafness

The averages for the size of adaptation (SA) at a stimulus intensity 20 db higher than at incipient adaptation were 10 2, 9 9 and 10 3 db at the three frequencies with a slightly smaller dispersion than in the normal series (Fig 7) Thus the SA was smaller than in normal subjects this difference is statistically significant

Initial adaptation in retrolabyrinthine deafness

As appears from the histograms (Fig 8) the average values for incipient adaptation (MSI) were 30 6 27 6 and 18 3 db at the frequencies 250 1000 and 4000 cps (Table 6) As in labyrinthine deafness the dispersion was somewhat greater than in the normal series although statistically significant only for 250 cps All the averages were significantly lower than in normal subjects The average values for SA were 11 7 11 4 and 12 3 db at the three frequencies with a somewhat smaller disperion than in the normal series

Table 5 *MSI and SA in labyrinthine deafness*

	Frequency	Age years	Average db	Standard deviation db
MSI	250	70	29 6	5 4
	1000	70	25 2	10 0
	4000	70	22 8	9 4
SA	250	70	10 2	3 0
	1000	< 70	9 9	3.3
	4000	70	10 3	3 9

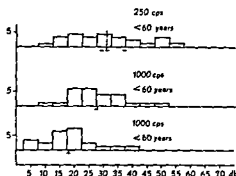


Fig 8 The distribution of MSI in retro labyrinthine deafness

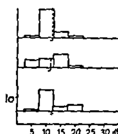


Fig 9 The distribution of SA in retrolabyrinthine deafness

Thus, the average was everywhere smaller than the corresponding value in normal subjects, but in none of the cases could the deviation be described as significant (Fig 9)

In this group, the size of the adaptation cannot with certainty be said to differ from the adaptation in the normal series

Initial adaptation in perceptive deafness with uncertain localization

In a group of 25 patients (10 women and 15 men) with hearing impairment of the perceptive type, it was not possible with certainty to decide whether or not recruitment was present All the patients in this "uncertain group revealed values for the MSI which were lower than in normal subjects The values obtained in this group were not subjected to statistical analysis, as it appeared that no significant difference could be demonstrated between perceptive deafness with and without recruitment

DISCUSSION

The investigations showed that with the technique used incipient adaptation occurs at the same intensity above the actual hearing threshold in patients with pure conductive deafness and in normal subjects In patients

TABLE 6 *MSI and SA in retrolabyrinthine deafness*

	Frequency	Age years	Average db	Standard deviation db
MSI	250	< 60	30 6	13 2
	1000	< 60	27 6	9 1
	4000	60	18 3	9 4
SA	250	< 60	11 7	
	1000	60	11 4	
	4000	60	12 3	

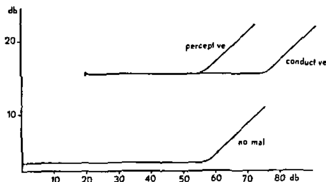


FIG 10 Path of the adaptation curve in normal individuals and in conductive and perceptive deafness Abscissa intensity of stimulus tone Ordinate intensity of test tone

with perceptive deafness, adaptation occurs at a considerably lower intensity in relation to the actual threshold By means of this method of examination it is thus possible to differentiate between conductive and perceptive deafness (Fig 10) However the examination makes such heavy demands on the patients and the dispersion of the results of measurement is so great that the method only in exceptional cases gives a possibility of clinical use in preference to other existing tests In particular, owing to the great dispersion of the results, the method cannot be used in hearing impairments of mixed conductive and perceptive type for the assessment of the quantitative influence of each of these types

The average values for MSI in otosclerosis are significantly lower than in normal subjects and in patients with pure conductive deafness, which must imply that it is the perceptive component of the hearing impairment which exerts its effect in patients with otosclerosis However, the dispersion is also here so great that it is not possible to derive benefit from the test in individual cases in clinical work

The phenomenon which is measured by means of the method with a frequency difference between the primary and secondary tones is assumed to be the spread of the primary tone on the basilar membrane with increasing intensity, as described by Gardner This spread is independent of a hearing impairment of the perceptive type which explains why, in patients with perceptive deafness incipient adaptation occurs at the same absolute intensity as in normal subjects Theoretically, there are no reasons to believe that this spread should differ in labyrinthine and retrolabyrinthine hearing impairments, and in agreement with this, identical values were obtained in the two groups of patients

As regards the size of the adaptation (SA) in the various groups of patients, the investigation showed that it is smaller in otosclerosis and labyrinthine hearing impairments than in normal subjects while in pure conductive deafness, it does not differ from the adaptation observed in normal subjects, apart from the frequency of 4000 cps It is hard to say why this frequency is

affected It may perhaps be explained by an incipient affection of the labyrinth, which cannot as yet be demonstrated in the pure tone audiogram In view of the low values obtained in labyrinthine hearing impairments, the fact that the adaptation is lower in patients with otosclerosis than in normal subjects must be explained by the perceptive component in this disease

In retrolabyrinthine hearing impairments, it could not be demonstrated that the size of the adaptation differed from the values obtained in the normal series However, the group was so small that it was not possible by statistical analysis to prove that the two groups behaved identically, and at any rate the inaccuracy of the measurements of the increase and the dispersion of the results were so great (measuring unit 5 db) that this method of examination cannot be used in the topical diagnosis of perceptive deafness

As already pointed out, increased values for the adaptation in patients with perceptive deafness have previously been observed (de Marc and Luscher & Zwislocki) The present study failed to reveal such increases, but this can scarcely be explained by the fact that the entire ' adaptation area" was not studied, which according to Luscher & Zwislocki would be necessary The measuring unit used (5 db) is possibly too large for a sufficiently accurate determination of the increase, but a smaller unit would scarcely be clinically applicable

It is possible that the decrease in the nerve activity observed by Matthews (1931) may be due to "mechanical adaptation" caused by a deformation of the connective tissue in the sensory end organ, by which the stimulation of the nerve is reduced Such a mechanical cause of auditory adaptation, as suggested by Ranke, Langenbeck and Kietz, does not seem likely, as it would then also be possible to demonstrate it in the microphonics Animal experiments have revealed evidence which renders it reasonable to assume that the adaptation occurs either in the synapsis between the hair cells and the peripheral nerve endings or in the nerve itself Adaptation is a normal function The mechanism of its change in hearing impairments of the perceptive type is unknown and it cannot be explained why the change in the adaptation seems to be the same whether the cause of the hearing impairment is to be found in the cochlea or the nerve *Even though the present* study failed to reveal a difference in the adaptation which could be utilized in the topical diagnosis of labyrinthine and retrolabyrinthine deafness it is of biological interest that it has been ascertained that such a difference probably does not exist It might be expected that the presence of recruitment would influence the size of the adaptation but it must be remembered that recruitment exerts an influence both on the stimulus tone and the test tone

One of the most important results of the study is that it must be concluded that the method may be used in the differentiation between conductive and perceptive deafness and thus be of value as a diagnostic aid in difficult cases In addition it is of theoretical interest that no definite difference in the size of the adaptation in labyrinthine and retrolabyrinthine deafness could be demonstrated

SUMMARY

The initial adaptation was measured in 192 patients with impaired hearing, by means of a short tone (30 msec) applied 50 msec after the cessation of a pure tone stimulus (1000 msec) The frequencies of the stimulus tone were 250 1000 and 4000 cps The frequency of the test tone was ½ octave above that of the stimulus tone The results were evaluated on the basis of normal values previously published (Sorensen, 1962) Patients with pure conductive deafness showed the same values as normal individuals In otosclerosis, the adaptation started at lower stimulus intensity, but was less pronounced In perceptive deafness the adaptation started at lower stimulus intensity, and the size of the adaptation was less than in normal subjects No definite difference in adaptation was found between labyrinthine and retrolabyrinthine deafness

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I am indebted to Mr E Niepoort, who performed the statistical analysis in this and the previous paper

ZUSAMMENFASSUNG

Die anfangliche Adaptation wurde bei 192 schwerhorigen Patienten mit Hilfe eines 50 msec nach dem Aufhoren eines reinen Stimuliertones (1000 msec) gegebenen kurzen Tones (30 msec) gemessen Der Stimulierton wurde in den Frequenzen 250, 1000 und 4000 Hz gegeben Die Frequenz des Testtones lag je eine halbe Oktave uber der des Stimuliertones Die Auswertung der Ergebnisse erfolgte auf Grund von kurzlich veroffentlichten Normalwerten (Sorensen, 1962) Patienten mit auf reine Leitungsstorung zuruckzufuhrender Taubheit zeigten die gleichen Werte wie normale Versuchspersonen Bei Otosklerose begann die Adaptation bei geringerer Stimulierungsintensitat war jedoch weniger ausgepragt Bei perzeptiver Taubheit begann die Adaptation bei geringerer Stimulierungsintensitat, und das Ausmass der Adaptation war geringer als bei normalen Versuchspersonen Kein deutlicher Unterschied konnte zwischen labyrinthischer und retrolabyrinthischer Taubheit festgestellt werden

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VASCULAR RESPONSES TO FEET COOLING IN NORMAL AND ALLERGIC NOSE

An analysis of some physical and physiologic variables

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A method for permanent simultaneous recording of the temperature of the mucosa on symmetrical points of both inferior turbinates has been devised Comparative measurements have been performed while the subjects are permitted to respire through only one of the nasal cavities while the other one is closed from air flow This approach permits an analysis of several external and internal factors influencing the temperature of the nasal mucosa By separating these factors an estimation can be made of how much of the temperature change measured is due to variations in peripheral blood flow during cold foot baths The same initial temperature fall in the nasal temperatures was found in both the ' normal ' and the vasomotor groups In the normals this fall was completely recovered while cold stimulus was still applied, as shown before, in the vasomotor patients, however, this initial fall was not recovered during the chilling period of 10 min This experimental finding appears to depend on reflex vasoconstriction of longer duration in patients with vasomotor rhinitis

It is a well known fact that local cutaneous cooling induces remote vascular reactions, which are most pronounced within the vascular regions of the skin, nose, and pharynx In the case of the nose the effect of chilling the skin was followed, *in most of the investigations made, by a transient temperature* drop in the mucosa, a change which is generally accepted to be caused by a reflex vasoconstriction Earlier, it was widely thought that this reaction, in combination with a cold virus, played an important part in the genesis of common cold In modern literature, however, the theory of this predisposing factor of cooling is abandoned (Dowling *et al*, 1958, Andrewes, 1960) Thus, for example, Andrewes writes 'In several instances chilling plus inoculation with a cold virus actually produced fewer colds than inoculation alone "

Yet further studies on vascular reactions within the mucous membranes seem very important Disturbed activity of the functional mechanism of the mucous membranes within ear and airways constitute some of the main problems of otolaryngology Several predisposing and causative factors in nasal diseases are still not well defined Thus according to many patients'

histories exposure to physical agents such as cold heat or a draught give nasal disorders This fact suggests that reflex vasomotor phenomena may play an important part in the development of the symptoms Therefore the present authors have tried to make further studies in this field on normals and on patients suffering from vasomotor rhinitis with the aid of a clinical method which involves measuring the temperature directly on the nasal mucosa

DISCUSSION OF EARLIER METHODS

Observed variations in the temperature of the nasal mucosa are generally considered roughly to reflect changes in the mucosal blood flow As seen in Table 1 the vast majority of the investigators have made temperature measurements with contact instruments applied directly on the mucous membranes Drettner (1961) made careful studies of vascular reactions within the nasal mucosa on exposure to cold Among many other methods he also introduced a heat radiation method for temperature studies without any contact between the measuring device and the mucosa This technique appears theoretically to be the most suitable since any local application of instruments easily induces mucosal swelling and increased secretion and thus precludes normal physiologic conditions

In studies of the nasal mucosa the accuracy of all surface temperature values obtained depends on several physical and physiological factors for example

(*a*) Varied contact between the respiratory air and the mucous membranes at different flow rates

(*b*) Disturbing thermal influence on the heat sensing element produced by direct contact between the wet instrument and the respiratory air Further there is always some uncontrollable influence exerted by radiant heat exchange between the thermometer instrument and the walls of the nasal cavity

(*c*) When contact instruments are used the measurements are complicated by the local irritant effect of the application itself Owing to changes in mucosal swelling there are variations in the length of the thermal pathway from the vessels through the tissues to the mucosal surfaces

(*d*) Variations in temperature and humidity of the inspired air

(*e*) Changes in the mucosal blood flow

As seen from all variables mentioned above it seems hardly possible with the aid of thermometry methods to solve the problem as to how much of an actually observed mucosal temperature change is purely physical and how much is physiologic i e due to variations in the peripheral blood flow Only direct measurements of the blood flow in the mucosa may give the complete answer provided such determinations could be done

The numerous and extensive studies published on the temperature of the

TABLE 1 *Earlier nasal temperature studies during skin cooling*

Earlier experiments	Application of temp instrument	Type of respiration during recording	Recorded nasal temperature °C: Before coolings	During cooling (with time for max change of temp min): Normals		Allergic rhinopathies	
Mudd Grant Goldman (1921)	Septum nasi Middle turb Inf turb	Nasal	About 34[a]	↓ 5	(0–15)	—	
Winslow Greenburg (1932)	Inf turb	Oral	29 2 29 8°	↑ 0 8	(—)	—	
Spiesman (1936)	nasal mucosa	Unmentioned	Incalculable in absolute values	↓	(5)		(5)
Spiesman Arnold (1937)	Inf turb	Unmentioned	36–36 5	↓ 0 8	(4)[a]	↑ 0 9	(5)[a]
Aschoff (1944)	an die lat Wande der ausseren Naseneingange	Unmentioned	33 5 35 5	↓ 0 5°	(3–4)[a]	—	
Ralston Kerr (1945)	Inf turb	Oral	34 35[a]	↓ 1 5	(2 3)[a]	↓ 1 5	(2 3)[a]
Pellegrini Riva (1949)	nasal mucosa	Nasal	31 5 33 5°[a]	↓ 1 5	(5)[a]	—	
Cole (1954)	Inf turb and submucous	Nasal	30 (postinsp)[a] 32 (postexp)	↓ 3[a]	(5 10)	—	
Drettner (1961)	Heat radiation method measuring temp from septum nasi and inferior turbinate	10 sec of apnoe before recording	*Normals* 32 7 33 1 *Allergics* 32 6–32 9 (mean values)	*Cooling of back (A) feet (B) general (C)* *A* 0 4 1 4 *B* 1 0 1 2 *C* 2 0–2 4 (mean values)	(5) (5) (5)	0 –1 0 6 1 3 2 8–2 9 (mean values)	(5) (5) (5)

[a] According to published temperature curves ↓ Maximum drop of nasal temperature
↑ Maximum rise of nasal temperature

skin clearly show that measurements and especially the interpretation of the values obtained in terms of blood flow are a complicated problem It is thus evident that mucosal temperature values are difficult to interpret not least because of the strong fluctuations of the surface temperatures simultaneous with the respiratory flow cycles The thermal capacity of the tissues involved further prevents any simultaneous estimation of the actual mucosal

blood flow as calculated from the surface temperature values which fail to follow time relations of change in blood flow. In order to reduce the respiratory sources of error all previous investigators have either made their subjects *hold their breath* or only permitted them to respire through the mouth during the moment of temperature determination for obtaining a temperature level.

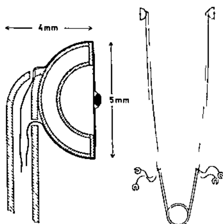
Now in order to make any estimation of the degree of mucosal blood flow with the aid of thermometry, several factors must be eliminated or at least kept constant during the experiment. This paper is to be regarded as an attempt to work according to the above mentioned principles and a modified direct thermometry method was accordingly devised (1957).

METHODS

The main principle in devising this instrument was to admit of a simultaneous permanent comparison of the temperatures in both the inferior turbinates directly measured on symmetrical points of the mucosa. The subject then respires through only one nasal cavity while the other one is completely closed. In this experiment the local irritant factor of the instrument applied within the nose is minimized and is exactly the same on both sides.

Temperature measuring device

Thermistors consisting of small electronic components were used (Stantel Thermistor type U 23, diam. 0.35 mm). They possess a negative thermal coefficient, i.e. their resistance falls with a rise in temperature and vice versa. Variation in resistance for a given temperature change is large enough to admit of measurement without elaborate circuitry. Wheatstone bridge circuits were used to indicate the changing resistances of the thermistors and the signals were recorded on a 2 channel ECG apparatus (Mingograph AB Elema, Stockholm). The thermistors were completely protected from direct thermal contact with the respired air by a double cup perspex device with an insulating air gap between the two cups (Fig. 1). The thermistors with carefully insulated lead wires were mounted on aluminium foils (thickness 0.05 mm), which have a very high thermal conductivity. Heat is then transferred to and from the element both by direct contact with the mucosa and from behind by the foil, which in its turn rests on the mucosa. The thermistors were mounted on a special clamp holder allowing free nasal respiration after application. The local pressure on the mucous membranes caused by this instrument did not exceed 5 g on each side. Furthermore it was always constant and equal on both sides during the experiment. After application the instrument completely screened the mucosa opposite the thermistor plate from the air flow (5 mm diam.). Such an insulation might interfere with the normal heat loss of the mucous membrane at the measured point. But the aluminium foil has a high thermal conduction to and from the mucosa not only at the measuring point but also from the whole foil area. Further the minimal clamp pressure against the mucosa cannot seriously



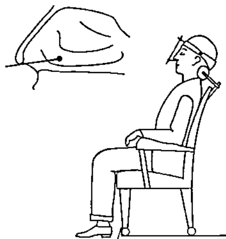


Fig 1 Fig 2

Fig 1 The perspex cups are mounted together The inner cup is closed by an aluminium foil outside of which the thermistor is mounted The thermistor clamp holder is to the right

Fig 2 Mode of instrumental application

impair the blood circulation Owing to these arrangements and in view of the special vascular pattern of the nasal mucosa the temperature recorded must be considered representative of that of mucosal regions exposed to the respiratory air flow surrounding the thermometer contact region

The thermistors were regularly calibrated in a water thermostat with the same equipment as that used in the nose The water temperature could be measured to an accuracy of +0 1°C

The performance of the experiments

The subject was sitting comfortably in an examination chair provided with a head rest The thermometer clamp construction was carefully introduced into the nasal cavities under visual control The thermistor plates were applied to the medial surfaces of both inferior turbinates at a distance of from about 1 5 to 2 cm from their anterior ends (Fig 2) The clamp holder was then outside the nose firmly fixed to a head mirror band Because of the delicate construction of the instrument the patient could breathe freely through the nose The patients were not markedly inconvenienced by increased secretion or by swelling of the mucous membranes during the experiments Local anesthesia was never needed

It is important to secure a perfect application of the thermistor plates on the mucous membranes before starting each experiment This was performed by checking that no changes of the mucosal surface temperatures simultaneous with the respiratory air flow cycles were recorded

The stages of the experiment

(1) Temperatures were recorded bilaterally during normal nasal respiration after 5 10 and 15 minutes counted from the moment of application

(2) Next that nostril which had the lowest mucosal temperature of the turbinate was always closed, by means of a cotton pack impregnated with paraffin tightly introduced into the vestibule. The patient thus respired only through the other open nostril during all further stages of the experiment. The temperatures were recorded bilaterally after a duration of 5 and 10 min now counted from the closing moment.

(3) The final stage of the experiment was to immerse the subject's feet in cold water (+12°C) in which they were kept for 10 min. The temperatures of both inferior turbinates were now recorded every second minute. The subjects respired ordinary room air only through one of the nasal cavities (temperature range 22 to 24°C, relative humidity 30 to 50 %).

MATERIAL

Normal group. Fourteen healthy volunteers (three women), aged between 14 and 56 years. Their clinical histories all gave a maximum frequency of two or three attacks of common cold yearly. None of them reported symptoms from the upper airways within the last two months before this investigation. In all cases findings were normal at rhinoscopy.

Vasomotor group. Seven men (ages ranging from 14 to 46 years). This material was selected from a large group of patients suffering from allergic rhinitis (200 cases). They all gave a history of nasal blockage in cold and were troubled by a watery discharge especially when moving from cold into a warm room. Rhinoscopic examinations revealed a normal or sometimes a pale, slightly oedematous mucosa. Intracutaneous skin tests were made with various inhalant and food antigens and were all negative. In spite of these negative cutaneous tests the patients were further tested on the skin and within the nose with house dust extracts derived from their own homes: all testing procedures were negative. None of the patients showed eosinophilia in the blood.

RESULTS

The temperature values obtained are presented in Figs. 3 and 4.

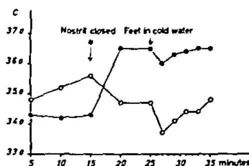


FIG. 3.

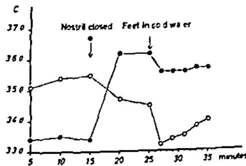


FIG. 4.

FIG. 3. Mucosal mean temperatures of 14 normal subjects. Feet in cold water for 10 min. ○ permanently ventilated cavity. ● cavity closed at first.

FIG. 4. Mucosal mean temperatures of seven patients with vasomotor rhinitis.

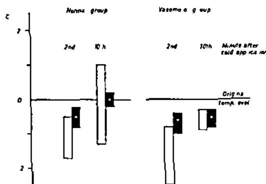


Fig 5

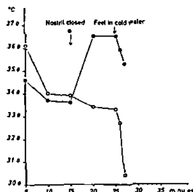


Fig 6

Fig 5 Ranges of all cooling temperature deviations from the original temperature level of mucosa immediately before cooling □, ventilated ■, unventilated nasal cavities Dots = mean temperatures

Fig 6 Mucosal temperature changes caused by abrupt fall in blood pressure

DISCUSSION

The circulating blood continually heats the surface of the nasal mucous membranes A momentary fall in blood pressure may be expected to yield a rapid fall in the mucosal temperature This phenomenon is illustrated in Fig 6, showing a subject who on one occasion collapsed when putting his feet in cold water The rapid rate of fall in mucosal temperature within the unventilated nasal cavity illustrates the central part played by the circulating blood as heater of the mucosa The rate of temperature fall in the ventilated side was increased still more owing to a further evaporative heat loss

The mucous membranes of the nose normally recover further heat by cooling expired air giving condensation of moisture Then during nasal breathing the temperature of the mucosa is 2 to 4°C lower than the interior of the body, at which temperature the warm, saturated air from the lungs reaches the nose

According to Burton (1940) measurements of skin temperatures are in adequate to indicate time and amount of transitory changes in the circula tion This problem must be still greater in mucosal temperature measure ments Thus Drettner (1961) using the heat radiation method writes It is impossible to avoid some degree of time lag in temperature measurements of these types The present authors tried to tackle this problem as follows

After one of the nostrils has been closed any heat loss by respiration is prevented and the mucosal temperature on this side rises to about 36 5°C as appears from Figs 3 and 4 The main temperature rise occurs within a relatively long period of 2 to 3 min and a constant temperature level is ob tained only after 5 min (Fig 7) This figure illustrates the thermal lag of the tissues involved the temperature being measured each minute after closing

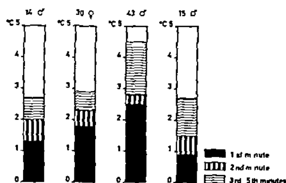


Fig. 7. The rate of mucosal temperature rise after closing the nostril (case ♂ 43 — common cold; the others — normal).

The rate of the temperature rise is 0.2–0.4°C per 10 sec during the first minute after closing. Because of the thermal capacity of the mucosal tissues these recorded changes of temperature can never be directly related to the actual blood flow during short apnoe periods. Furthermore, because of the thermal lag of the instruments used not even momentary values of the mucosal temperature can be determined. The combination of both these factors makes any interpretation of the values obtained in terms of blood flow impossible. Thus temperature values obtained during short nasal apnoe or oral breathing only do not seem acceptable from either a physiological or a physical point of view. To judge from reports in the literature no authors have hitherto studied the complex responses to skin cooling by comparing the mucosal temperature of a ventilated with that of a permanently unventilated side at the same time. This seems to be the best way of obtaining an estimation of the order of temperature changes caused by physical mucosal cooling from the physiologic temperature changes following a vasoconstriction caused by remote cooling of the skin.

Naturally every thermometer application directly on the mucosa causes local irritation, but the method devised reduces the influence of this factor on the temperature values determined. Thus a relative comparison of the temperatures on both sides is made during equal and constant conditions of irritation. The irritant effect appears to be comparatively small when temperature levels are fairly constant both in normal and vasomotor groups during the period 5–15 min (Figs. 3, 4). One might expect a greater tendency *towards mucosal oedema formation in the vasomotor* group during the experiments, which might bias the values obtained by increasing the length of the thermal tissue pathway between the blood vessels and the surface of the mucosa. But after closing one nostril the temperatures rise at the same rates and to the same levels in both groups. Furthermore, during cooling periods the temperatures began to fall with the same readiness, started at the same moment and reached their maxima simultaneously. These temperatures do not seem to be disturbed by increased length of the thermal pathway caused by oedema.

In all measurements made during bilateral nasal respiration the mucosal temperature curves showed no significant difference between the normal and the vasomotor groups During the further course of each experiment the subject was permitted to respire only through the initially warmer nasal cavity Despite the fact that now all respiration was made through this cavity only a moderate fall in the turbinal temperature (1°C) to a relatively constant level followed (timed 15 25 min) This illustrates the remarkable efficiency of the nose in warming the inspired air

Cooling experiments

A comparison of nasal symptoms in the normal and the vasomotor groups during the cooling period (10 min) yielded no significant difference None of the subjects was troubled by increased nasal discharge or by marked blockage of the nose In spite of the fact that histories of obvious discomfort in connection with cold were given by all members of the vasomotor group yet they could breathe without any marked obstruction through only a single nasal cavity during the cooling experiments

In the normal group both curves have the same initial drop configuration and a complete bilateral temperature recovery to initial values before cooling takes place within the experimental time (Fig 3 timed 25–35 min) It is generally held that the main cause of this temperature reduction followed by complete recovery is a reflex vasoconstriction of short duration in spite of further cold stimulation On the ventilated side however, the initial temperature falls were more pronounced because of further loss of heat evaporation

In the vasomotor group the initial temperature drops were of the same rate and order as those within the normal one On the unventilated side, however the initial mean temperature fall remained unchanged during the whole cooling period From the temperature curves obtained it seems possible to conclude that cooling of the feet for 10 min leads to a reduction of the convective transfer of heat by the flow of blood in comparison with that of normals A moderate temperature recovery occurs on the ventilated side which may depend on heat recaptured by the mucous membranes during condensation

From Fig 5 appear the total ranges of all cooling temperature deviations from the original temperature level of the mucosa measured immediately before cold stimulus application The temperature ranges obtained on the unventilated sides 2 and 10 min respectively after start of cooling (black zones) are very limited in both groups including 11 normal subjects and seven cases of vasomotor rhinitis The initial temperature fall is never recovered in the vasomotor group The normal group however completely recovers the initial temperature fall The temperature deviation ranges on the ventilated sides (blank zones) are much wider For this reason interpretations can hardly be made since there is an additional thermal effect of respiratory factors

The present studies show a vasoconstriction in the lower turbinal mucosa

of longer duration in the vasomotor group than in the normal group Such difference in the duration of the vasoconstriction induced by cooling of the feet (+12°C) during 10 min was not demonstrated in earlier studies (according to Table 1)

ZUSAMMENFASSUNG

Eine Methode zur laufenden, gleichzeitigen Registrierung der Schleimhauttemperatur symmetrischer Punkte der unteren Nasenmuscheln wird beschrieben Vergleichende Messungen sind ausgefuhrt worden, bei denen die Versuchsperson je weils nur durch die eine Nasenoffnung atmen konnte, wahrend die andere von der Luftzufuhr abgeschlossen wurde Dieses Verfahren ermöglicht eine Analyse verschiedener ausserer und innerer Faktoren, die die Temperatur der Nasenschleimhaut beeinflussen Durch einen Ausschluss dieser Faktoren kann man eine Auffassung davon bekommen, ein wie grosser Teil der beobachteten Temperaturveränderungen auf Variationen des peripheren Blutstroms wahrend kalter Fussbader beruht Der gleiche initiale Temperaturruckgang der nasalen Schleimhauttemperatur wurde in sowohl der normalen als der Vasomotor Gruppe beobachtet Bei den Normalfallen stieg die Temperatur wieder auf normale Werte, wahrend der Kaltestimulus noch anhielt, was schon vorher gezeigt worden ist, bei den Vasomotor Patienten dagegen sah man wahrend der 10 Minuten, unter welchen die Abkühlung stattfand, keine Normalisierung der Temperatur Diese experimentellen Ergebnisse scheinen darauf zu beruhen, dass die reflektorische Vasokonstriktion bei Patienten mit einer vasomotorischen Rhinitis von langerer Dauer ist

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AN IMPROVED TECHNIQUE OF THE ULTRASONIC IRRADIATION OF THE VESTIBULAR APPARATUS BY MÉNIÈRE'S DISEASE

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The A. describes a new technique of the ultrasonic surgery which he proposed since 1953 for the treatment of severe cases of Ménière's disease. By this new technique complications such as facial palsy or paresis and postoperative recurrence of vertigo are minimized. The A. refers the results obtained with this technique by 97 operated patients (Oct. 1960–1961).

The destruction of the vestibular apparatus with ultrasonic waves in patients suffering from Ménière's disease that do not respond to medical treatment is by now a widespread method among otologists.

After my introduction and detailed technical description of this method in 1952 and my publication of the first favourable results in 1953 there have been numerous confirmations of its effectiveness (Lumsden, Angell James, *Aragno, Altmann & Waltner, Tato, Fortunato, Ironside & Lindsay*, Ruedi & Dubs, de Prest, Beck, Wolfson, Lindahl & Robertson, Herrmann, Mundnich, Falk, etc.). Authors have unanimously confirmed that in many cases hypoacusia and tinnitus improve after irradiation.

In fact the principle that led me to introduce the ultrasonic method in the surgical treatment of Ménière's disease, in accordance with the ethical law that no surgical intervention aiming at the treatment of a morbid organ should damage a neighbouring organ beyond repair, *is that in the therapy of Ménière's disease vertigo must be definitely eliminated without loss of hearing*.

The most extensive report of cases (over 700) operated by this method (1952–1961) was presented by me at the VIIth International Congress of Otorhinolaryngology in Paris (July 1961).

Recently *some authors have repeatedly pointed out two possible negative* aspects of this method, namely (1) facial palsy, (2) persistence of vertiginous attacks after the intervention.

The possibility of these occurrences, and therefore of failure of the ultrasonic method, have been pointed out in many of my reports ever since the beginning of my surgical experience. On those occasions they were thoroughly discussed and the application of operative devices was suggested in order to avoid such occurrences (Arslan 1953).

The percentage of these complications in our first group of cases was never over 6.5 % *for facial palsy or light paresis and 10.1 % for persistence of vertigo*. Besides, we reported the following important facts:

(1) Facial paralysis (which in some cases is incomplete and may thus be defined as paresis and disappears in a few days) is cured completely in two to three months time Only in three out of the 700 cases that we operated by this method did it last over a year

(2) The persistence of vertigo after intervention has three different clinical forms (*a*) *positional vertigo quite different from the preoperative one due* to the persisting activity of the otolithic receptors which have not yet been destroyed by the slowly progressive atrophy caused by ultrasonic irradiation These vertiginous attacks always disappear within a few months after the operation (*b*) typical Menière vertigo equal to the preoperative one its presence proves that the irradiation has been insufficient and should be repeated In our 1st group of cases 4 per cent of the cases were re operated (*c*) vertigo of a psychoneurotic and psychosomatic nature whose diagnosis is often difficult but can always be reached with the help of a neurologist These cases require long and patient assistance from both otologist and neurologist After a year or more they improve very remarkably owing to the fact that the complete recovery from the organic factors of the Menière attacks (after ultrasonic irradiation) deprives the psychoneurosis of its primitive organic cause and reduces it very greatly

Improvement of the ultrasonic method

To improve further the technique of the ultrasonic method and to help those who have had only limited experience with it or who intend to use now it in the past two years I have made some other changes to the original technique They are illustrated in this report These changes result from some physiopathological postulates of Menière s disease and from the outcoming of experimental research work undertaken in our Clinic on the particular endolymphatic currents and the consequent functional effects that the ultra sound beam causes (*a*) by its thermal action and (*b*) by its ultrasonic action operating in the neurosensory epithelium of the vestibular receptors

The modifications in the technique are as follows

(1) To make sure that the ultrasound beam has reached and actually destroys the vestibular receptors *observation of a very clear nystagmus during the operation is absolutely necessary*

Therefore the use of too strong pre anaesthetics (as such containing sco polamine chloropromazine and other similar substances) is to be avoided since they have a depresssing effect on the bulbar centres and the bulbo mesencephalic reticular substance whence the nystagmus originates and make the patient too sleepy Also *cold irrigation of the mastoid cavity during irradiation is not advisable* in fact when irradiation is performed with irrigation the nystagmus is likely to appear reduced to very small jerks if not absent altogether for many minutes cold irrigation depresses the thermal power of the irradiating beam and consequently inhibits nystagmus *But this fact is not usually attributed to the effect of irrigation but is believed to be*

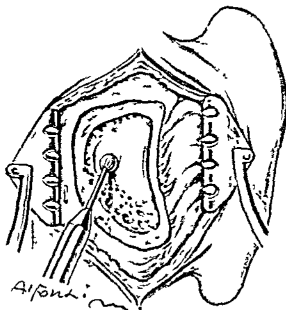


Fig 1

caused by insufficient intensity of ultrasound Thus the operator is tempted to increase the ultrasound intensity This must, however, be avoided since it has been proved to be dangerous and might provoke a facial palsy

Another reason for lack of nystagmus is an incorrect direction of the ultrasound head *Such a mistake can easily be detected by moving the head properly when the irradiation is performed*

In other words, the nystagmus that is to be observed during irradiation and that is *also* due to the thermal effect of the beam reaching the labyrinth is the *only certain indication* that the receptors have been reached by the irradiating beam

Therefore we must try to obtain a clear and quite marked nystagmus, it is not necessary, however to reach a III degree amplitude (according to Alexander), and a frequency of 1 jerk in 0 5 , which corresponds to an excessive intensity of the ultrasonic beam (dangerous to the facial nerve) A II degree amplitude and a frequency of about 3 jerks in 2 of the nystagmus are sufficient

If a nystagmus of this amplitude and frequency would by chance only be obtained by 3–4 watt/cm² ultrasonic intensity, it is quite useless to increase the irradiation intensity In other words *it is evidence of a marked nystagmus which leads the irradiating intensity and the operative procedure and not vice versa*

(2) As the observation of an evident and marked nystagmus is essential to the success of the operation, the surgical procedure requires that the utmost care should be given to the following points (*a*) the assistant in charge of

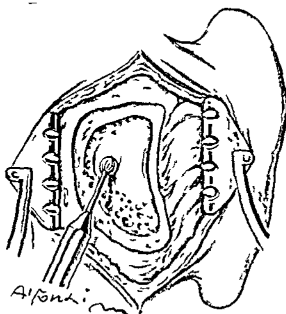


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(2) As the
the success of
care should I

the observation of the nystagmus is constantly to watch the patient s eyes and inform the operator of the amplitude frequency and variations of the induced nystagmus (*b*) if a certain direction of the irradiating head produces no nystagmus the direction should be slowly changed on all spatial planes till nystagmus appears Once it does appear the irradiating head should be held in position quite still and the intensity increased only when nystagmus after some minutes begins to decrease (*c*) the direction of the nystagmus is not of essential importance It is nearly always irritative in type but it may also be paralytic from the onset of the irradiation This occurs owing to the anatomical disposition of the semicircular canals or the particular position given to the ultrasound head The same consideration applies to the form of the nystagmus it is not important whether with the irradiation of the lateral semicircular canal it is vertical instead of horizontal or vice versa (*d*) in subjects that before the operation showed vestibular hyporeflectivity on the side to be irradiated nystagmus from ultrasonic irradiation may appear less intense This fact however is not to be taken as a rule since we observed that very many cases showing no vestibular excitability to caloric stimulation preoperatively revealed later a conspicuous nystagmus from ultrasound

(3) 23 30 irradiation time is the *optimum* time for an effective irradiation in fact after 20 23 the nystagmus always tends in a varying degree to diminish

(4) During irradiation it is absolutely necessary to check the tuning of the irradiating apparatus two or three times An *automatic* tuning control (con structed by Professor De Biasi) has recently been applied to the Federici new model ultrasound apparatus in our Department and it has proved to be of great help in the operator s task

(5) The most important method to avoid facial palsy is first the one mentioned above that is *always to obtain a clear and very marked nystagmus during the irradiation time In fact when the operator does not attain a marked nystagmus as I have already said he tends to increase the intensity of the ultrasound beam and this may be dangerous* Irrigation of the mastoid cavity is therefore not advisable in that it can prevent the appearance of a marked nystagmus

(6) The nearer the tip of the ultrasound head is to the Fallopian canal the more likely the occurrence of facial paralysis For this reason two years ago we devised a change of technique as follows *The flattening with the drill is no longer performed on the convexity of the semicircular canal but behind it towards the vestibule of the semicircular canal only the posterior part is flattened In this way a little cup like cavity of a grey colour (the enchondral bone) is made in which the tip of the ultrasound head is applied Its position is thus closer to the vestibule and the otolithic and ampullar receptors than when the tip is placed on the convexity of the lateral semicircular canal* (Fig 1) It is not quite necessary to reach the blue line to obtain a satisfactory nystagmus to avoid the blue line means avoiding *certainly* the danger of *opening the labyrinth*

	Symptom free	Persistent	Recurred
Vertigo	83	3	11
Facial palsy or paresis	2[a]	—	—
		Total 97 cases	

[a] 1st case M. L. (Hosp. reg. n. 465) male, left ear, appeared six hours after irradiation. Complete recovery after 1 month.
2nd case S. O. (Hosp. reg. n. 2132), male, right ear, appeared during the irradiation. Considerably improved after 8 months.

(7) The assistant's observation of the patient during irradiation must be constant, thorough, careful, and must always include both the observation of the patient's facial muscles, in order to detect any sign of facial involvement, and the observation of the nystagmus mentioned above. If even the the least and most transitory sign of trouble of the facial nerve (very brisk and involuntary twitching) should appear, the irradiation should be stopped at once. In so doing, we noted in many cases that the facial nerve recovered its normal function even in the course of the intervention.

Results

From October 1960 to the present day 97 cases have been operated with these technical modifications. The results and the occurrence of lesions of the facial nerve are illustrated in the table herein enclosed.

ZUSAMMENFASSUNG

A. beschreibt eine neue Technik der seit 1953 eingeführten Methode der Zerstörung des Vestibularapparates, bei schwerer Ménièreschen Krankheit, mit Ultraschall. Diese Modifikation scheint die geeignetste zu sein um die Fazialislähmung und das Rezidiv von Schwindelanfällen zu beseitigen. Die Resultate dieser Modifikation bei 97 operierten Fällen (Okt. 1960–1961) werden diskutiert.

RÉSUMÉ

L'A. décrit une modification de sa méthode de destruction ultrasonique de l'appareil vestibulaire dans les cas graves de Ménière. Cette méthode a été proposée par l'A. déjà en 1953. La modification assure la protection du nerf facial, et réduit au minimum la récidive des crises de vertige. Dans le travail sont exposés les résultats obtenus par cette nouvelle technique sur 97 cas operés (oct. 1960–1961).

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ANATOMICAL AND PHYSIOLOGICAL EFFECTS OF CHRONIC SECTION OF THE EIGHTH NERVE IN CAT

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Section of the eighth nerve caused a degeneration of the unmyelinated fibers in the tunnel of Corti followed by loss of the ganglion cells in the modiolus and degeneration of the eighth nerve Two days after section of the eighth nerve the N_2 was found to disappear Three days after section of the eighth nerve the N_1 was found to disappear After the N_1 and N_2 disappeared a new neural like potential called the W phenomenon was observed The degeneration of the unmyelinated fibers was associated with the disappearance of the N_1 and N_2

Previous studies have demonstrated the effects of acute section of the eighth nerve in cat (Fisch & Ruben 1962) It was found that when the eighth nerve was cut with preservation of the blood supply to the cochlea the cochlear potential and the N_1 N_2 remained It was concluded that the N_1 and N_2 had their origin distal to the brain stem and probably within the eighth nerve itself

The anatomical and physiological changes in the eighth nerve and cochlea following chronic section of the eighth nerve have been studied (Hallpike & Rawdon Smith 1935 Kanda 1931 Wittmaack 1911) These studies revealed that when the eighth nerve was sectioned with preservation of the blood supply there was a degeneration of the cochlear division of the eighth nerve including the spiral ganglion cells The vestibular division of the eighth nerve including Scarpa s ganglion did not degenerate (Fig 1) The hair cells of the cochlea and the vestibular apparatus also remained intact [illegible] logical studies have shown that the cochlear potential was not affected [illegible] long term chronic section of the eighth nerve (Kiang & Peake [illegible]) The N_1 and N_2 was found to disappear in animals in which the section [illegible] carried out at least one month prior to the recordings (Kiang & Peake [illegible])

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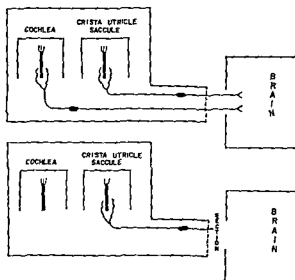


FIG 1 Schematic representations of effect of chronic section of the eighth nerve The cochlear division of the eighth nerve degenerates leaving the vestibular division of the eighth nerve including Scarpa's ganglion intact The haircells of both vestibular and cochlear divisions remain unaffected

The following experiments were carried out to correlate the disappearance of the N_1 N_2 with the anatomical changes which followed the section of the eighth nerve. In the course of the experiments a new electrical phenomenon was noted.

METHOD

Two groups of adult cats were used The first group, the chronic group, consisted of nine animals in which the eighth nerve was sectioned with preservation of the blood supply to the cochlea. The bulla on the sectioned side was explored eight to 206 days after the operation (Table 1) The second *group, the semi-chronic group, consisted of 23 animals in which the eighth*

TABLE 1 *Number of days after section of the eighth nerve in chronic animals*

Cat no	No of days
275	8
199	45
251	74
200	78
171	90
248	98
223	124
252	137
221	204

TABLE 2 *Effect of semi chronic section of the eighth nerve*

Time hours	No of animals in group	N_1		N_2		W	
		Present	Absent	Present	Absent	Present	Absent
0	1	1	0	1	0	0	1
6	1	1	0	1	0	0	1
12	2	2	0	2	0	0	2
24	4	4	0	4	0	0	4
36	3	3	0	3	0	0	3
48	3	3	0	2	1	0	3
60	3	1	2	0	3	2	1
2	4	0	4	0	4	4	0
96	1	0	1	0	1	1	0
120	1	0	1	0	1	1	0

nerve was sectioned in a similar fashion The bulla on the operated side was explored from 0 to 120 hours after section (Table 2) All the experiments were carried out under nembutal anesthesia 30 mg per kilogram A mono polar electrode consisting of a small ball tip of no 27 gauge silver wire was placed on the round window membrane These were led into a Tektronix type 122 preamplifier which was set to record from 0 8 cps to 1000 cps This was further amplified by a Tektronix type 502 cathode ray oscilloscope The resultant potentials were recorded by means of a Grass camera

The clicks were generated by means of a 0 07 msec square wave delivered through an RS 3 Isophone electrostatic speaker The intensity of click was attenuated in 10 db steps from maximum value of 0 db (0 db equals 50 volts across the speaker terminals) The speaker was placed an equal distance between the ears in front of the animals The pure tones were generated by a Hewitt Packard oscillator and delivered through a db attenuator to an ear phone speaker This speaker was placed 6 cm from the external auditory meatus of the animals The sound pressure was calibrated in a free field with a Western Electric type 640 A A condensor microphone

At the conclusion of each experiment the animals were perfused with normal saline and 10 % formalin The brains were separated from the tem poral bones and the temporal bones were decalcified and mounted in celloi din They were then sectioned at 30 micra and stained with Ehrlich s hema toxylin and eosin

RESULTS

I Chronic Group

Effects of the cochlear potential

The sound intensities needed to produce a 10 microvolt cochlear potential response with pure tones was the same for the normal ears as the ears with the eighth nerve sectioned (Fig 2)

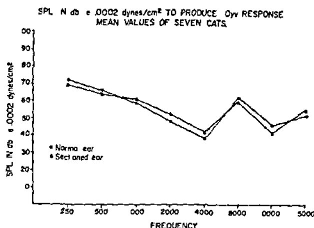


Fig. 2. No difference was noted in the sound pressure level needed to elicit a 10 microvolt response between the ears with normal innervation and those with chronic section of the eighth nerve.

Effect on the N_1 and N_2

The N_1 and N_2 were absent in the ears in which the eighth nerve was sectioned. A different electrical phenomenon was observed in eight of the nine animals. It consisted of two positive deflections differing from the negative deflections of the N_1 and N_2. This wave form resembled a W and will be referred to as the W phenomenon. The first positive deflection was the W_1 and the second positive deflection was the W_2 (Fig. 3). The latencies of the N_1 and N_2 in the non sectioned ears and the W_1 and W_2 in the sectioned ears were averaged and their standard deviations calculated (Table 3). The mean latency of the N_1 peak measured from the beginning of the cochlear potential was 1.15 msec with standard deviation of plus or minus 0.27 msec. The N_2 peak had a mean latency of 2.01 msec with a standard deviation of plus or minus 0.19 msec. The latency of the W phenomena was measured in a similar manner. The W_1 peak had a latency of 2.1 msec with standard deviation of

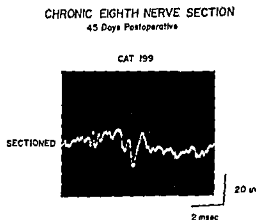


Fig. 3. W phenomenon in cat 45 days after section.

CHRONIC EIGHTH NERVE SECTION

ROUND WINDOW RESPONSES TO CLICK

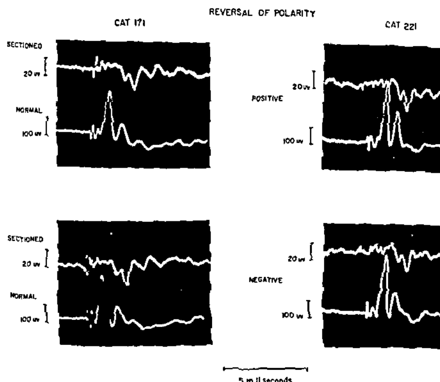


FIG 4 W phenomenon and the N_1 N_2 do not change polarity with the change in polarity ... ck stimulus

TABLE 3 *Latency of N_1, N_2 and W_1, W_2 responses as measured from the begin... the cochlear potential*

	Measurements (in msec) taken to the peak			
	Normal ear		Sectioned ear	
Cat no	N_{1p}	N_{2p}	W_{1p}	W_{2p}
200	1.2	1.9	2.0	2.6
251	1.3	2.4	2.4	3.0
248	1.1	2.0	1.9	2.4
223	1.0	1.8	2.0	2.5
221	1.1	1.9	1.9	2.4
252	1.2	2.0	2.3	3.0
199	1.0	1.8	2.2	2.7
275	1.4	2.3	2.2	2.8
171	1.1	2.0	2.0	2.8
Average	1.15	2.01	2.1	2.64
	±0.27	±0.19	±0.17	±0.87

Each of the above figures represents an average of ten measurements made on different tr...



FIG 7 Cat 252 normal ear showing unmyelinated fibers in the tunnel of Corti



FIG 8 Cat 252 l ft ear 13 days after section Note the absence of unmyelinated fibers in the tunnel of Corti

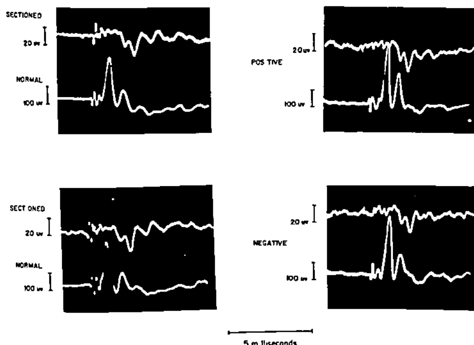


Fig 4 W phenomenon and the N_1 N_2 do not change polarity with the change in polarity of the click stimulus

TABLE 3 *Latency of N_1, N_2 and W_1, W_2 responses as measured from the beginning of the cochlear potential*

	Measurements (in msec) taken to the peak			
	Normal ear		Sectioned ear	
Cat no	N_{1p}	N_{2p}	W_{1p}	W_{2p}
200	1.2	1.9	2.0	2.6
251	1.3	2.4	2.4	3.0
248	1.1	2.0	1.9	2.4
223	1.0	1.8	2.0	2.5
221	1.1	1.9	1.9	2.4
252	1.2	2.0	2.3	3.0
199	1.0	1.8	2.2	2.7
275	1.4	2.3	2.2	2.8
171	1.1	2.0	2.0	2.8
Average	1.15	2.01	2.1	2.64
	±0.27	0.19	±0.17	±0.87

Each of the above figures represents an average of ten measurements made on different tracings

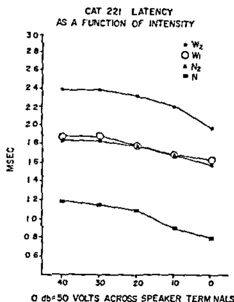


FIG 5 The N_1 and N_2 and W_1 and W_2 decrease in latency with increase in stimulus intensity

plus or minus 0 17 msec The W_2 peak had a latency of 2 64 msec with a standard deviation of plus or minus 0 87 msec It was noted that the W_2 on the operated side and the N_2 on the non operated side seemed to be coincident in time

The W phenomenon was tested in several ways The polarity of the stimulus was changed The cochlear potential changed with the change in stimulus polarity The W phenomenon and the N_1 and N_2 on the opposite side did not change with the change of polarity (Fig 4)

Latency studies were carried out It was noted that with an increase in the stimulus intensity, both the N_1, N_2 and W_1 W_2 decreased in latency (Fig 5)

The effect of anoxia on the W phenomenon was studied in six cats These were given lethal injections of nembutal and recordings were made simultaneously from the sectioned and non sectioned ears The N_1 and N_2 response

TABLE 4 *Time of disappearance of cochlear potential after fatal injection of nembutal*
Time (in minutes) measured from beginning of injection of nembutal

Cat no	Cochlear potential	N_1	N_2	W phenomena
171	25	18	16	16
200	< 15	13	11	10
221	< 15	12	10	10
248	< 16	12	9	10
252	< 11	11	9	9
223	< 20	12	10	10

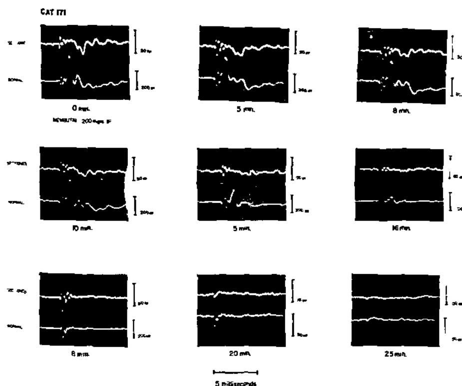


FIG 6 The N_1, N_2 and W phenomenon disappear at approximately the same time after a lethal injection of nembutal The time indicated in the illustration was the time after the injection of a lethal dose of nembutal

and the W phenomenon disappeared at the same time (Table 4) The cochlear potential remained visible in both ears for a longer period of time (Fig 6)

Histology

The histology of the nine animals in the chronic group was varied All the cats except one had complete section of the eighth nerve Some of the animals had the glial portion of the eighth nerve distal to the section whereas others had it proximal to the section Some animals had a moderate degeneration of Scarpa's ganglion whereas in others there was only minimal degeneration of Scarpa's ganglion In all of the animals in the chronic group there was one finding in common There was total degeneration of the cochlear division of the eighth nerve All the animals also demonstrated an occasional ganglion cell still remaining in the modiolus The unmyelinated fibers in the tunnel of Corti the space between the inner and outer haircells was absent in all of the chronic animals (Figs 7 and 8)



Fig 7 Cat 252 normal ear showing unmyelinated fibers in the tunnel of Corti



Fig 8 Cat 252 left ear 137 days after section Note the absence of unmyelinated fibers in the tunnel of Corti

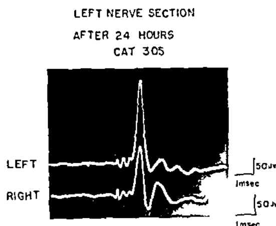


Fig 9 Cat 305 24 hours after section Note the presence of the N_1 N_2

II Semi Chronic Group

Effect on the cochlear potential

The sound intensities needed to produce a 10 microvolt response with pure tones were the same for the normal ear as those with the eighth nerve sectioned

Effect on the N_1 N_2

The results of the semi chronic section of the eighth nerve on the N_1 and N_2 are tabulated in Table 2 The N_1 and N_2 was found to be present in most animals up to 48 hours (Figs 9 and 10) The N_2 disappeared approximately 12 hours before the N_1 After 72 hours the N_1 and N_2 were both absent and

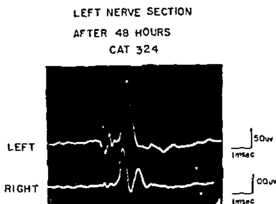


Fig 10 Cat 324 48 hours after section Note the presence of the N_1 and the absence of the N_2

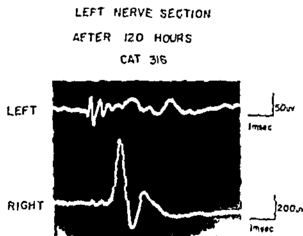


Fig 11 Cat 316 120 hours after section Note the disappearance of the N_1 and N_2 and the appearance of the W phenomena

the W phenomenon was present (Fig 11) The W phenomenon was not seen without both the N_1 and N_2 being absent Two of the animals showed a *questionable* N_1 response associated with the W effect One of these animals was explored at 72 hours and the other at 96 hours

The labyrinth of the normal ear was destroyed in three animals in which the W phenomenon was observed Following the destruction of the labyrinth the W phenomenon could still be recorded from the operated side The mean latencies of the W_1 peak in this group was 2 2 msec and the W_2 peak was 2 7 msec

Histology

The eighth nerve was completely sectioned in 90 per cent of the animals in this group There was no degeneration of the eighth nerve or of the ganglion cells *within the modiolus All of the animals in which both the N_1 and N_2* disappeared and the W phenomenon was present demonstrated a marked degeneration of the unmyelinated fibers in the tunnel space between the inner and outer haircells (Fig 12)

DISCUSSION

The histological changes in both groups demonstrated a sequence of events Degeneration of the unmyelinated fibers in the tunnel space between the inner and outer haircells occurred first and was usually complete at the end of seventy two hours This was followed by the simultaneous loss of the ganglion cells in the modiolus and a degeneration of the cochlear division of the eighth nerve Some of the animals also demonstrated a moderate degeneration of the vestibular portion of the eighth nerve



Fig 12 Cat 316 section ear 120 hours after section Note the absence of the unmyelinated fibers

Two days after the section of the eighth nerve the N_2 was no longer observed The N_1 disappeared approximately three days after the section of the eighth nerve At the same time that the N_1 disappeared there was noted a biphasic positive potential called the W phenomenon This occurred with the same latency as the N_2 in the opposite ear The W phenomenon was found not to reverse polarity with change of stimulus polarity It was found to be as sensitive to anoxia as the N_1 and N_2 In addition to this the W phenomenon decreased in latency as the stimulus intensity was increased

The anatomical changes after section of the eighth nerve revealed one common finding The disappearance of the N_1 and N_2 and the appearance of the W phenomenon was associated in time with the degeneration of the unmyelinated fibers in the tunnel space It would appear that the N_1 was dependent upon the innervation of the outer haircells Whether there was a degeneration of the fibers to the inner haircells which was associated with the loss of the N_2 could not be determined

The origin of the W phenomenon was obscure The W phenomenon was definitely a neural like potential in that it did not reverse polarity was very sensitive to anoxia and increased in latency with an increase in the stimulus intensity There were two possible sources in the ears with the chronic section of the eighth nerve which would account for such a neural like potential

The vestibular apparatus in these cochleas was at least moderately intact All of the animals had some of Scarpa s ganglion left The W phenomenon

may be the neural potential of the vestibular apparatus in response to a click stimulus. This hypothesis was tested in mice who had degeneration of their cochlea or of their cochlea and saccule. The electrical potentials recorded from a mouse's round window were of a small voltage and were electrically noisy. No W phenomenon was observed in these deaf mice in which the cochlea had degenerated. This does not completely exclude the possibility that the source of the W phenomena was the vestibular apparatus. The recordings from the mice may have had too small a signal to noise ratio to see the W phenomenon with conventional means.

Another possibility was that the W phenomenon had its origin within the haircells. This may be a physiological potential which was masked by the N_1 and N_2. It also could be an injury potential which was the result of having the haircells denervated.

RÉSUMÉ

La section totale du huitième nerf cranien a causé une dégénération des fibres non myélinisées traversant le tunnel de Corti, suivie d'une perte de cellules ganglionnaires du modiolus et d'une dégénération du nerf auditif. Deux jours après la section du huitième nerf cranien, la disparition du phénomène N_2 a été observée. Trois jours après la section du huitième nerf cranien, le phénomène N_1 disparaissait aussi. Après la disparition de N_1 et de N_2 un nouveau phénomène, semblable à un potentiel neural, nommé le phénomène « W » a été observé. La dégénération des fibres non myélinisées traversant le tunnel de Corti était associée à la disparition de N_1 et N_2.

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BEMERKUNGEN ZUR ARBEIT VON VUORINEN UND MEURMAN „THE BASAL ANGLE IN THE CLINICAL DIAGNOSIS OF OTOSCLEROSIS"

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Mit grossem Interesse haben wir die oben genannte Arbeit von Vuorinen und Meurman im II. Heft der *Acta Oto-Laryngologica* (1962, 54, 176) gelesen und freuen uns, feststellen zu konnen, dass die Resultate ihrer Untersuchungen trotz anscheinender Widerspruche mit unseren langjahrigen Studien in Einklang stehen. Um Missverstandnissen vorzubeugen, glauben wir, dass einige Bemerkungen und Erlauterungen unsererseits angebracht waren.

In einer Reihe von Arbeiten der letzten Jahre haben wir die Aufmerksamkeit der Forscher auf anthropologische Faktoren bei der Entstehung der Otosklerose gelenkt. Auf diese Gedanken wurden wir durch folgende Beobachtungen gefuhrt. Die Knochenaffektion der Otosklerose, die als „Osteodystrophia fibrosa localisata" (Nager, Weber) erkannt wurde, bleibt nur auf die Labyrinthkapsel beschrankt. Sie entwickelt sich fast immer gleichzeitig auf beiden Seiten, und zwar an bestimmten Prädilektionsstellen. Weiterhin ist die Otosklerose eine spezifisch menschliche Krankheit, sie kommt bei Tieren spontan nicht vor (13). Sie ist bei den Negern (Guild (3), Rosen (8)) ausserst selten, ebenso wie bei den Indianern (Tato (17) und bei den Japanern (Takahashi (16), Šercer–Krmpotić (15)). Dies waren fur uns aber nur allgemeine Indizien. Ganz eindeutig wurde dagegen unsere Aufmerksamkeit auf die in der Schadelbasis innewohnenden mechanischen Krafte durch unsere Untersuchungen uber die ontogenetische Entwicklung der Labyrinthkapsel gerichtet. Die Untersuchungen wurden ausgefuhrt an 233 kompletten Serien zerlegter Schadel vom 3monatlichen Embryo bis zum Neugeborenen, und an 110 Schlafenbeinen vom Neugeborenen bis zum 25. Lebensjahr, also im ganzen an 343 Objekten.

Aus diesen Untersuchungen ging namlich deutlich hervor, dass die knocherne Kapsel des menschlichen Labyrinths ihre Form vom Beginne der Ossifikation im intrauterinen Leben bis zur Pubertat im Sinne einer Rotation der Kochlea nach vorne und oben andert (11). Die bekannten franzosischen Anthropologen Delattre und Fenart haben diese „Rotation der Kochlea" an 33 Tierarten (darunter an Primaten und an Anthropomorphen) nachgepruft und vollauf bestatigt.

Wahrend der Ontogenese kommt es also zu einer wahren „Verschiebung der Kochlea nach vorne", weil der Clivus infolge der Entstehung des aufrechten Ganges die Schadelbasis „bricht" und weil so unterhalb der Schadelbasis eine direkte Krafteinwirkung zum Ausdruck kommt. Daraus haben

wir gefolgert, dass in der Schadelbasis in welcher das Labyrinth verborgen ist ursachliche oder wenigstens begunstigende Momente fur die Entstehung der Otosklerose liegen mussen

Der wesentliche Unterschied zwischen der Schadelbasis des Menschen und des Tieres ist also die Knickung der Schadelbasis als Schadelbasis Kyphose (*S B K*) genannt Die S B K ist nur eine Teilerscheinung der Anpassung des Schadels und der Wirbelsaule auf neue statische und mechanische Bedingungen bei der Aufrichtung der Korperachse Bei Tieren ist die Schadelbasis flach oder sogar konkav Nur beim Menschen ist sie geknickt Bei gewissen Menschenrassen ist die Knickung der Schadelbasis weniger ausgepragt als bei der weissen Rasse was mit der Tatsache in Zusammenhang steht dass die Haltung der Wirbelsaule bei verschiedenen Rassen verschieden ist Der Grad der Knickung der Schadelbasis wird durch den Sphenoidalwinkel gemessen Von der Geburt bis zur Pubertat wird die *Knickung immer starker Nach Sieglbauer (9) betragt der Sphenoidal* winkel beim Neugeborenen ungefahr 140–130° und beim Erwachsenen ist er ungefahr 120° *Extreme Werte* (nach Welcher gemessen) sind nach unseren Befunden beim Neugeborenen ungefahr 140° und beim Erwachsenen ungefähr *110°* Der Grad der Basisknickung andert sich auch nach der Pubertat bis zum Alter als Folge der Anpassung der Schadelbasis auf Altersveranderungen der Wirbelsaule Die S B K ist also nicht etwas Unveranderliches sondern etwas was sich durch das ganze Leben hindurch den wechselnden statischen Bedingungen der Wirbelsaule anpasst Ja es ist in der letzten Zeit gelungen eine Anderung der Schadelbasisform auch experimentell an Ratten (Moss (5)) hervorzurufen

Nach unseren Untersuchungen (14) die an 390 mazerierten median durchsagten Schadeln verschiedenen Alters ausgefuhrt worden sind verkleinert sich der sphenoidale Winkel vom 15 bis zum 85 Lebensjahr um volle 6 (sechs) Grade was zweifellos eine signifikante Zahl ist Denn man muss sich vergegenwartigen dass *eine Verkleinerung des Sphenoidalwinkels nur um einen Grad schon eine deutlich erkennbare Folge an allen anatomischen Strukturen unterhalb der Schadelbasis hat* (10) woruber man sich leicht an Modellen uberzeugen kann *Diese Tatsache betonen wir mit besonderem Nachdruck* Der kompressive Effekt der sogenannten Schadelbasiszange welche sich vom intrauterinen Leben bis zum Alter allmahlich schliesst hangt von folgenden drei Momenten ab 1 von der Entfernung des Objektes vom Drehpunkt der Schadelbasis 2 von der Form des Objektes und 3 von der Struktur des Objektes Wie Delattre und Fenart (1) betonen befindet sich das Labyrinth an der empfindlichsten Stelle der Schadelbasis In dieser Hinsicht sind Abbildungen 8 9 und 10 der Arbeit dieser Autoren (2) im Bulletin der Anthropologischen Gesellschaft in Paris ausserst instruktiv Die Rotation der Kochlea um ungefahr 60° nach vorne oben und ihre Torsion im Laufe der ersten Lebensjahre ist nur deswegen ohne funktionelle Schaden moglich weil sich in der interfenestralen Gegend der Labyrinthkapsel ein umbaufahiger Knochen befindet

Wenn Vuorinen und Meurman bei 25 Fallen von Otosklerose den Basis winkel von 120 bis 139° (am Rontgenbild gemessen) gefunden haben so steht das vollkommen in Einklang mit unseren Untersuchungen Ein grosser Winkel (um 140°) entspricht otosklerotischen Veranderungen im hinteren oberen also im stummen Teile des Labyrinths ein kleiner Winkel (um 120°) entspricht der Lage pathologischer Prozesse in der Kochleargegend und ein Winkel von ungefahr 130° entspricht otosklerotischen Veranderungen gerade in der Fenstergegend Siehe daruber unseren Bericht auf dem Internationalen ORL Kongress in Paris 1961 (12) Unter einem kleinen Basiswinkel verstehen wir einen solchen der sich 120° nahert und unter einem grossen einen solchen welcher um 140° liegt Nach unseren bisherigen Erfahrungen spricht in zweifelhaften Fallen ein kleiner Basiswinkel zu Gunsten der Otosklerosediagnose ein grosser Basiswinkel spricht nicht dagegen Denn durch neueste Untersuchungen von Delattre und Fenart (2) wissen wir dass auch bei einem grossen Basiswinkel die mechanische Einwirkung auf den Labyrinthkern zum Vorschein treten kann wenn der Labyrinthknochen zu fruh seine Umbaufahigkeit verloren hat Ja sogar eine Streckung der Schadelbasis wie sie bei der Platibasie vorkommt ruft auffallende Formveranderung des Labyrinthkernes hervor wie das J Krmpotic an zwei mazerierten Schadeln beobachten konnte (4)

Bei dieser Gelegenheit bemerken wir dass Padovan und Krmpotic an mazerierten Schadeln feststellen konnten dass die Langsachse des ausseren Gehorgangs paralell mit dem Clivus Blumenbachi verlauft Von der Neigung des ausseren Gehorganges ist die Übersichtlichkeit der Fenstergegend bei der Operation abhangig (6) Andererseits haben Sercer und Krmpotic gefunden dass die Ebene des lateralen Bogenganges der Ebene des Planum sphenoidale entspricht Aus den zuletzt erwahnten zwei Angaben kann man auch am lebenden Menschen den Grad der Schadelbasiskyphose aproximativ beurteilen (14)

Schliesslich noch einige Worte zur Technik der Messung des Basiswinkels Die Intensitat der Schadelbasisknickung kann man auf verschiedene Weise beurteilen woruber wir in anthropologischen Arbeiten nahere Angaben finden (Virchow Welcher Landzert Delattre usw) Wir haben den Basiswinkel in den ersten Studien nach Welcher und in denjenigen welche an mazerierten median zersagten Schadeln ausgefuhrt wurden nach Landzert gemessen Der erste Winkel ist grosser und der zweite ist kleiner als der Winkel welchen Vuorinen und Meurman gemessen haben Nur an mazerierten median zersagten Schadeln lassen sich verlassliche Werte erhalten Ja sogar mazerierte und median zersagte Schadel muss man hie und da unberucksichtigt lassen wenn der Clivus Blumenbachi deformiert ist An Rontgenogrammen (auch an mediansagittalen Planigrammen) kann man wissenschaftlich einwandfreie Daten uber den Basiswinkel nicht immer erreichen Ja wir haben sogar an mazerierten Schadeln von welchen wir Rontgenogramme anfertigen wollten die charakteristischen anthropologischen Punkte mit Bleikugelchen markiert (10) Die Werte welche vom

Röntgenogramm des Lebenden abgemessen werden müssen, sind nur aproximativ und mit Vorsicht zu gebrauchen. Siehe darüber die Arbeit von G. Pankow über Schädelbasisknickung und konstitutionelle Gesamtreifung (7) und die Diskussion, die danach folgte. Deswegen gebrauchen wir in der Praxis nur solche mediansagittale Planigramme, aus welchen der Grad der Schädelbasisknickung einwandfrei abzulesen ist.

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ZUR MECHANIK DER SCHALLÜBERTRAGUNG DURCH DAS MITTELOHR

Die Leistung des Trommelfelles

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In einer früheren Arbeit konnten wir an Hand akustischer Messungen darlegen, daß der Schalleitungsapparat des Mittelohres auch bei der Übertragung von Tönen, die über 2000 Hz liegen, maßgeblich beteiligt ist (Schwetz und Cancura). *Die Frage nach der Übertragungsart von Tönen im höheren* Frequenzbereich interessiert ja heute nicht mehr allein im Rahmen hörphysiologischer Erwägungen, sondern sie ist auch wegen der Abklärung postoperativer Ergebnisse nach hörverbessernden Operationen brennend aktuell geworden (Schwetz). Auf Grund experimenteller Untersuchungen kommt Lüscher zur Ansicht, daß die Trommelfellmembran der *mechanisch* empfindlichste Teil der Schalleitungskette ist. Es war daher naheliegend, daß das Studium der funktionellen Auswirkungen von Trommelfelldefekten Rückschlüsse auf seine physiologische Leistung erlaubt. Im Vordergrund des Interesses stand die Abhängigkeit des Hörverlustes von Lokalisation und Größe der Trommelfellperforation. Im großen und ganzen wurden dafür zwei Untersuchungswege eingeschlagen: 1. Tierexperimentelle Arbeiten mit artefiziell gesetzten Trommelfelläsionen und Abnahme von cochlearen Potentialströmen (Wever, Wagemann, Crowe und Hughson, Bordley und Hardy, Payne und Githler). 2. Kritische Beurteilung der audiologischen Messungen an Patienten mit Trommelfellperforationen (Zöllner, Meyer zum Gottesberge, Müller, Pietrantoni und Bocca). Auf diese Untersuchungen werden wir zum Teil bei der Besprechung unserer eigenen Ergebnisse noch näher einzugehen haben, wir möchten aber schon jetzt betonen, daß gegen diese angeführten Untersuchungen gewisse Bedenken geltend gemacht werden: 1. Eine große Anzahl von Autoren steht der Messung der Cochlearpotentiale im Tierversuch mit Skepsis gegenüber. 2. Die audiologische Befundung von Patienten mit Trommelfellperforationen läßt mögliche pathologische Veränderungen im Mittelohr selbst unberücksichtigt.

Zur Prüfung der Leistung des Schalleitungsapparates schien uns das menschliche Schläfenbein auch für Untersuchungen nach experimentell gesetzten Trommelfelldefekten als am besten geeignet. Grundlage und Voraussetzung dafür sind die bekannten Arbeiten v. Békésys. Durch Verwendung einer empfindlicheren als der akustischen Meßtechnik gelang es uns, die

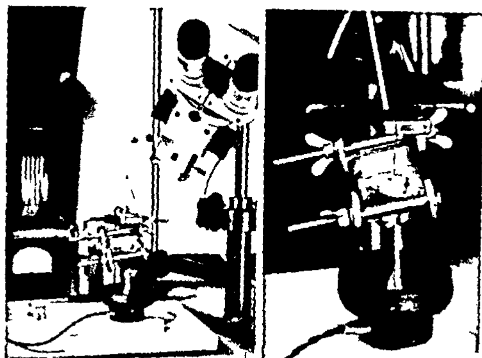


Abb. 1a und 1b. Versuchsanordnung (Erklärung im Text)

Verminderung der Schalltransmission in ihrer Abhängigkeit von der Lokalisation der Trommelfelläsion sowohl in quantitativer Hinsicht (Schallintensität in db) als auch qualitativ (Frequenzabhängigkeit) zu erfassen.

Die Versuche wurden an insgesamt 23 menschlichen Schläfenbeinen durchgeführt, die bei otoskopischer Inspektion anatomisch normale Verhältnisse des Trommelfelles aufwiesen, so daß Störungen durch entzündliche oder narbige Veränderungen ausgeschlossen werden konnten. Die Messung der Steigbügelschwingungen erfolgte auf der labyrinthären Seite der Fußplatte. Zu diesem Zweck wurde die Pyramidenspitze etwa 8–10 mm lateral vom Porus acusticus internus in sagittaler und schräg nach medial und caudal gerichteter Schnittführung mit der Säge abgetrennt. Dabei gelang es, das Vestibulum labyrinthi in einer Ebene nahezu parallel zur Fußplattenebene in großem Ausmaß freizulegen, ohne dabei die Tuba Eustachii anzuschneiden.

Um eine möglichst genaue Messung zu erhalten, wurde das Schläfenbein in einer Haltevorrichtung so fixiert, daß die Fußplattenebene annähernd horizontal war (Abb. 1). Die Audiometertöne konnten auf diese Art ohne Schwierigkeit mittels eines mit kurzem Gummischlauch versehenen Hörers dem äußeren Gehörgang zugeführt werden. Auf einen guten schalldichten Abschluß war dabei zu achten, da sonst eine Schallintensitätsminderung im Gehörgang auftreten und der austretende Ton bei größeren Intensitäten den Abnahmekopf direkt erregen hätte können.

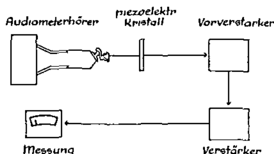


Abb. 2. Schaltschema

Da Audiometerhörer erfahrungsgemäß bei der Tonabstrahlung eine beträchtliche Eigenschwingung aufweisen, mußte der für diese Versuche verwendete Hörer auf Schaumgummi gebettet werden, um so ein Mitschwingen der gesamten Versuchsanlage zu verhindern. Die Abnahme der Fußplattenschwingung erfolgte mit einem piezoelektrischen Kristall, an dem eine ca. 4 cm lange Nadel aufgekittet war. Mit der Nadelspitze konnten auf diese Weise die entsprechenden Abschnitte der Fußplatte abgetastet werden. Um den gesamten Abnahmekopf mit der Nadel in entsprechender Lage zu halten und einen konstanten Druck auf die Fußplatte auszuüben, wurde der Abnahmekopf durch einen Seidenfaden über Rollen und einem Gegengewicht über der Steigbügelplatte gehalten. Durch Änderung des Gegengewichtes konnte der Auflagedruck eingestellt werden.

Die elektrischen Potentiale des Kristalles wurden durch zwei hintereinander geschaltete Röhrenverstärker so weit verstärkt, daß entsprechende Ausschläge an einem am Ausgang des letzten Verstärkers liegenden Wechselspannungs-Meßgerät zu verzeichnen waren (Abb. 2).

Die Messungen wurden in der Form durchgeführt, daß vorerst am Schläfenbein bei intaktem Trommelfell durch Regelung der zugeführten Tonintensität in den Frequenzen von 128 Hz bis 4000 Hz eine willkürlich angenommene Marke am Meßinstrument eingestellt und die nötige Schallenergie in db registriert wurde. Die Marke wurde weit über der Schwelle der Ansprechbarkeit der gesamten Anlage gewählt, um bei den späteren Vergleichsmessungen genauere Werte zu erhalten (logarithmische Skaleneinteilung). Trotz dieser an eine überschwellige Audiometrie erinnernden Messung konnten im Vergleich zu früheren Untersuchungen (Schwetz und Cancura) bei intaktem Trommelfell und intakter Gehörknöchelchenkette die aufgewendeten Schallenergien auf Grund der großen Leistungsfähigkeit der Verstärkeranlage sehr nieder gehalten werden. Sie bewegten sich im Durchschnitt zwischen 40 und 50 db, in einzelnen Fällen konnten schon bei 25 und 30 db verwertbare Ausschläge erhalten werden. Nach diesen ersten Messungen wurden die entsprechenden Veränderungen am Trommelfell (wie weiter unten näher ausgeführt) vorgenommen und in einer neuerlichen Messung die Schalleitungsminderung durch größere Schallenergiezufuhr

ausgeglichen, so daß wieder die gleichen Fußplattenschwingungen erreicht wurden. Dieser Vorgang ließ sich mit Hilfe des Audiometers leicht durchführen, so daß sehr genaue Meßergebnisse erhalten werden konnten.

Da bekanntlich der zugeführte Ton den gesamten Knochen direkt oder indirekt (über den Weg des Gummischlauches) in Schwingung versetzen kann, war auf diesen Umstand zu achten, um Fehlmessungen zu vermeiden. Es zeigte sich jedoch bei der gegebenen Versuchsanordnung, daß eine meßbare Schwingung an beliebigen Stellen des Schläfenbeines erst ab einer Schallintensität von 80 db in allen Frequenzen auftrat. Desgleichen war auch eine Erregung des Abnahmekopfes durch Streuschall aus dem Audiometerhörer nur bei höheren Frequenzen und erst ab 90–100 db festzustellen.

Diese Kontrollmessungen zeigten also deutlich, daß sich die bei unseren Versuchen verwendeten Prüftöne energetisch in einem Bereich befanden, der noch mit Sicherheit Fehlmessungen der Fußplattenschwingung ausschloß.

Nach den Untersuchungen v. Békésy's führt der Steigbügel keine reine kolbenförmige Bewegung aus, sondern wird gleichzeitig um verschiedene Achsen gedreht, so daß die Exkursionen der Fußplatte nicht an allen Punkten gleich sind. Um eine Beeinflussung dadurch zu vermeiden, führten wir die Messungen grundsätzlich nur an einer bestimmten Stelle durch und wählten dafür den Mittelpunkt der Fußplatte, die auf der labyrinthären Seite eine kleine Delle aufweist, was für das Aufsetzen der Nadel von Vorteil war.

Nach Lokalisation und Größe der gesetzten Trommelfelläsion unterschieden wir vier verschiedene Typen:

Typ I. Die Pars flaccida (Shrapnell'sche Membran) ist entfernt, das übrige Trommelfell bleibt intakt.

Typ II. Außer der Pars flaccida sind auch die beiden *vorderen* Quadranten des Trommelfelles entfernt.

Typ III. Außer der Pars flaccida sind auch die beiden *hinteren* Quadranten des Trommelfelles entfernt.

Typ IV. Außer der Pars flaccida ist auch der *untere* Trommelfellanteil nach einer horizontalen Schnittführung in Höhe des Umbo entfernt.

Diese Versuchsanordnung brachte es mit sich, daß der Typ I an sämtlichen Präparaten gemessen werden konnte.

ERGEBNISSE

Nach den jeweils erzeugten Trommelfelldefekten wurde mittels der angeführten Meßtechnik eine graduell verschiedene Verminderung der Schalltransmission und zwar im *gesamten* geprüften Frequenzbereich, d. h. von 128 Hz–4096 Hz gefunden. Auf die Prüfung noch höherer Frequenzen mußten wir der technischen Anlage wegen leider verzichten. Die präoperativ gefundenen Meßwerte wurden als normale Schwellenkurve ange-

nommen und die, durch den verringerten Schalldruck erzielten Differenzwerte als „Hör-Verlust-Kurven in „db" audiographisch dargestellt (Abb. 3).

Besprechung der Ergebnisse

Ohne unsere Untersuchungen mit audiologischen Messungen am menschlichen Gehörorgan oder mit der Abnahme von Cochlearpotentialen im Tierversuch vergleichen zu wollen, scheint es doch nicht uninteressant, diese auf so verschiedenen Wegen gefundenen Ergebnisse fallweise einander gegenüberzustellen.

Typ I. Die Entfernung der Shrapnell'schen Membran verursacht bloß eine Verminderung der Schallintensität um 1–5 db (Abb. 3, Kurve 1). Auch aus klinischer Sicht bewirkt ein Defekt der Pars flaccida des Trommelfelles kaum eine Höreinbuße, weshalb Zöllner ausdrücklich unterstreicht, daß es „aus akustischen Gründen völlig nutzlos sei, eine epitympanale Perforation zu verschließen.

Typ II. Das Fehlen der *vorderen* Trommelfellanteile zieht eine ziemlich lineare Verringerung der Schalltransmission in allen geprüften Frequenzen nach sich (Abb. 3, Kurve 2). Der Maximalwert liegt mit 26 db bei 1500 Hz, aber auch die 4000 Hz Frequenz läßt noch eine Einbuße um 22 db erkennen. Damit scheint, im Vergleich zu anderen Abschnitten, dem *vorderen* Trommelfellbereich eine größere Bedeutung für die Übertragung der höheren Frequenzen zuzukommen. Ähnliches finden nicht nur Payne und Githler im Tierversuch, sondern Pietrantoni und Bocca stellen auch audiometrisch an ihrem Patientengut fest, daß das Hörvermögen bei vorderen Trommelfellperforationen besonders für die Frequenzen über 2000 Hz verschlechtert ist.

Typ III. Nach Entfernung der beiden *hinteren* Trommelfellquadranten sehen wir eine relativ gleichmäßige Verminderung der Schallintensität, wobei der niedrigste Wert mit 14 db bei 4000 Hz liegt (Abb. 3, Kurve 3). Payne und Githler fanden, daß Perforationen im hinteren Trommelfellbereich den größten Hörverlust für die Frequenzen zwischen 100 Hz und 2000 Hz verursachen. Pietrantoni und Bocca beobachteten dabei eine Hörverschlechterung besonders für die Frequenzen unter 1000 Hz. Eine solche stärkere Beeinflussung des Tieftonbereiches konnten wir bei unseren Messungen nicht wahrnehmen.

Typ IV. Die Excision der *unteren* Trommelfellhälfte führt bis zur *2000* Hz Frequenz zu einem durchschnittlichen Verlust von 20 db (Abb. 3, Kurve 4); die Werte in diesem Tonbereich weichen somit von denen des Typ III kaum nennenswert ab. Ein Ergebnis, das durchaus überrascht, da nach den Untersuchungen v. Békésys die Transmission und Verstärkungsleistung des Trommelfelles vor allem auf dem mit dem Hammergriff verbundenen oberen und nicht auf dem unteren Trommelfellabschnitt beruht. Nach unseren Beobachtungen kommt dem letzteren weniger funktionelle Bedeutung für [illegible] equenzen zu

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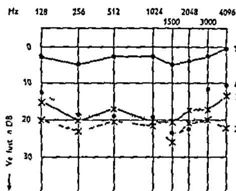


Abb. 3. Schalleitungsminderung in db. 1. Nach Entfernung d. Pars flaccida (Kurve 1). 2. Nach Entfernung d. Pars flaccida u. d. *vorderen* Trommelfell-Quadranten (Kurve 2). 3. Nach Entfernung d. Pars flaccida u. d. *hinteren* Trommelfell-Quadranten (Kurve 3). 4. Nach Entfernung d. Pars flaccida u. d. *unteren* Trommelfell-Hälfte (Kurve 4).

Die experimentell gewonnene und von den theoretischen Fachgebieten noch immer aufrecht erhaltene Ansicht, daß die Schalleitungskette für die Übertragung höherer Töne als 2000 Hz unwirksam sei, begegnet seitens der Klinik immer mehr Kritik und Ablehnung. Auch Ranke meint, daß die physiologischen Aussagen über die Luftleitung bei hohen Tönen tatsächlich revisionsbedürftig sind. Verständlicherweise fehlt es nicht an Versuchen, dieses Problem audiologisch oder experimentell zu lösen. Dabei verstärkt sich die Auffassung, daß Trommelfell und Gehörknöchelchenkette auch eine funktionelle Wertigkeit bei der Transmission höherer Töne besitzen. So kommt z. B. Lüscher durch Trommelfellbelastung zu dem Schluß, daß eine Schalleitungsstörung auch ein Absinken der hohen Töne verursachen kann. Auch die Auswirkungen hörverbessernder Operationen im Mittelohr deuten nach Meyer zum Gottesberge in dieselbe Richtung. Auf optischem Wege sieht Dahmann, daß die Gehörknöchelchen selbst auf sehr hohe Pfeiftöne mit meßbaren Schwingungen ansprechen.

Konnten wir an Hand von Schalldruckmessungen am menschlichen Schläfenbein unsere Untersuchungen auch nur in den Tonbereich bis 4000 Hz ausdehnen, fällt doch in quantitativer und qualitativer Beziehung eine überraschende Übereinstimmung mit den Ergebnissen elektrischer Potentialmessungen auf. Danach beträgt der Hörverlust durch Trommelfelldefekte zwischen 10 bis 20 db (Wever, Bordley und Hardy, Wagemann) und nimmt bis 28 db zu, wenn 30 % der Trommelfellfläche entfernt wurden (Payne und Githler).

Zusammenfassend zeigen unsere Untersuchungen:

1. Trommelfelldefekte führen zu einer Schalldruckabnahme in *allen* geprüften Frequenzbereichen (bis 4000 Hz).

2. Die Schalldruckverminderung nach Entfernung der Pars flaccida des Trommelfelles ist minimal und kann vernachlässigt werden.

3 Die *vordere* Trommelfellhälfte besitzt für die Übertragung höherer Töne besonderen Wert

4 Ein ähnlicher Wert scheint der *hinteren* Trommelfellhälfte für die Übertragung tieferer Töne *nicht* zuzukommen

5 Die *untere* Trommelfellhälfte ist für die Übertragung von Tönen bis 2000 Hz den anderen Trommelfellanteilen funktionell gleichwertig

SUMMARY

The question of transmission of sound through the middle ear was studied on human temporal bones by measuring piezo electrically the vibration of the footplate of the stapes Since the drum seems to be mechanically speaking the most sensitive part of the chain of sound transmission, 23 drums were injured on different parts Thus we were able to state the effects of reduction of sound transmission in intensity (in db) as well as in frequencies

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STUDIES OF CRISTOSPINAL REFLEXES (LATEROTORSION)

III Patterns of Cristoocular and Cristospinal Reflexes in Clinical Oto neurology

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A comparative study of caloric nystagmus vertigo and laterotorsion was made in normal subjects and in patients with peripheral labyrinthine lesions Ménière s disease meningo encephalitis and brain tumors Variations were found in the patterns of behaviour in the various lesions As examples in Ménière s disease nystagmus and vertigo decreased in their responses to caloric stimulation but laterotorsion remained normal while meningo encephalitis showed a normal response of nystagmus but a decrease in laterotorsion

This induced us to consider the hypothesis that cristo ocular and cristo spinal reflexes have different mechanisms modulating them despite the common origin of their stimulus The possibility of different receptor cells and neurons for the cristo ocular and the cristo spinal reflexes was also discussed A better resistance of the units involved in the vestibulo spinal reflex would then also explain the normal caloric laterotorsion in Menière cases

A pilot study of brain tumors indicated that different localities of the tumors produce different patterns of behaviour of nystagmus vertigo and laterotorsion

In order to perform accurate oto neurologic examinations methods must be devised for obtaining physical measurements of the movements of the eye and body resulting from known vestibular stimuli The use of the previously described method of synchronous recording of the cristo ocular (nystagmus) (3 6) and the cristo spinal reflex (laterotorsion) (7) is regarded as a feasible first step in such examinations To evaluate such measurements in patients the normal reactivity patterns of these responses must be known With this in view a study of the reflex responses to caloric stimulation according to the principles of Fitzgerald & Hallpike (2) was previously made in

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normal volunteer subjects (8) This is now *followed by* the present study of measurements of the same reflexes in clinical cases

METHODS

At the oto neurologic clinic of the University of Lund all patients with vertiginous complaints are examined according to the following routine clinical otolaryngologic and neurologic history and examination audiometry electronystagmographic and laterotorsion recording The nystagmographic records include spontaneous optokinetic positional gaze and calorically induced nystagmus (5)

The saw tooth variations of voltage produced by nystagmus movements of the eyes are recorded by a derived method presenting the speed of the slow component directly as a level above a base line This makes possible a slower speed of the recording paper on which the speed of the slow component will appear like a spike the height of which will correspond to the speed of the slow component of each nystagmus stroke

The cristo spinal reflex records depend on pneumatic pressure differences caused by the twisting movements of the body as expressed by the head and neck in response to a labyrinthine stimulation

In addition to the objective recordings notes were made of the patient s subjective evaluation of the accompanying vertigo using Lidvall s method (9)

When studying the caloric vestibular reactivity in normals (8) six properties were examined They were (1) maximum eye speed (3) subjective vertigo (3) maximum laterotorsion (4) time for onset of maximum nystagmus (5) time for onset of maximum laterotorsion (6) remaining laterotorsion when the accompanying nystagmus has subsided

For the present paper only measurements of caloric nystagmus (maximum eye speed) vertigo and laterotorsion were performed This is because calorically induced nystagmus and/or laterotorsion are absent or just discernible in many pathological conditions making it impossible or difficult to determine the times for maxima and for endpoints in these reactions Accordingly properties 4 5 and 6 were not studied in the present paper while the first three qualities of each clinical group were compared with the same properties in the normal material previously reported (8)

Routine records were used measuring the reflexes of the patients with the lesions studied Well trained medical technicians prepared these records for clinical use

MATERIAL

Seventy patients representing seven different categories of balance disease were collected as they presented themselves at the vestibular laboratory (see Table 1)

TABLE 1. *Distribution of the clinical material studied*

Category		No. of patients	Age span, years	Sex
Normal subjects		25	14–38	13 males 12 females
(1) Vestibular neuronitis		9	36–60	3 males 6 females
(2) Acoustic neurinoma		5	23–61	1 male 4 females
(3) Severe congenital neural deafness		12	11–36	6 males 6 females
(4) Oto toxic damage		10	17–78	7 males 3 females
Streptomycin	7			
Kanamycin	3			
(5) Ménière's disease		14	34–67	8 males 6 females
(6) Meningo encephalitis		10	9–36	3 males 7 females
(7) Brain tumors		10	18–62	8 males 2 females
Cerebral	6			
Cerebellar	3			
Brain stem	1			

Nine cases of vestibular neuronitis ranging from 36 to 60 years of age formed the first group. Five cases of acoustic neurinoma from 23 to 61 years constituted the second. Twelve patients aged 11 to 36 were referred by the School for the Deaf to form group three. All the people in this group exhibited small island of hearing in the lower tones and normal intelligence. Their hearing was so limited that, in order to learn to speak, laborious deaf mute training had been necessary. All but two of these patients demonstrated definite labyrinthine reflexes some of which, however, were slight. Ten cases of oto toxic lesions were found and studied as group four. The symptoms of seven of these patients, varying from 17 to 78 years of age, developed after the administration of streptomycin (11). The other three, between 31 and 55 became giddy after kanamycin administration (4).

Group five was made up of 14 patients with Ménière's disease, their ages varying from 34 to 67 years. They all had the unilateral variety of the disease.

The infectious lesions comprising group six were represented by ten cases of meningo encephalitis varying from 9 to 36 years of age. Only cases with pathological findings in the cerebrospinal fluid secured by lumbar puncture were used.

Group seven was made up of ten patients with brain neoplasms. The selected cases were all confirmed at surgery or by X ray. If the latter method was used both angiography and air studies of the ventricles were employed.

TABLE 2 *Patterns of labyrinthine reactions in patients with different pathological conditions*

Category	Nys tagmus	Vertigo	Latero torsion	Hearing
Normals	0	0	0	0
Pattern I				
Vestibular neuronitis	—[c]	—[c]	—[c]	0
Acoustic neurinoma	—	—	—	—
Severe congenital neural deafness	—[c]	—[c]	—[b]	—
Oto toxic damage	—[c]	—[c]	—[a]	— (4 10)
Pattern II				
Ménière s disease	—[c]	—[b]	0	—
Pattern III				
Meningo encephalitis	0	0	[b]	0
Pattern IV				
Cerebral tumors	—	—	—	0
Pattern V				
Cerebellar tumors	—	—	+	0
Pattern VI				
Brain stem tumor	0	0		0

0 normal value or insignificant variation — decrease from normal activity + increase from normal activity

[a] Almost significant difference [b] Significant difference [c] Highly significant difference

Material for brain tumors was not statistically treated in view of their small number

An effort was made to have cerebral cerebellar and brain stem lesions re presented Six cerebral lesions three in the frontal lobe, two in the temporal and one in the parietal lobe were present in patients varying from 18 to 62 years of age Three cerebellar tumors in individuals ranging from 21 to 59 constituted this subgroup One single pontine tumor in a 59 year old woman represented the only brain stem lesion in our material

This completed the case material submitted for analysis It is summarized in Table 1

FINDINGS

Fig 1 shows in a graphic form the means of maximum nystagmus vertigo and laterotorsion of normal individuals and patients with peripheral vesti bular lesions These are unilateral lesions of vestibular neuronitis and acoustic neurinoma and the bilateral lesions of oto toxic damage and of severe congenital neural deafness Examination of this figure reveals that the nystagmus vertigo and laterotorsion all show a decrease from normal values when the affected ears were stimulated The responses from the unaf

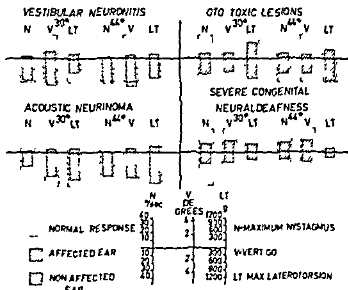


Fig. 1. Graphic representation of mean nystagmus, vertigo and laterotorsion in caloric reactions of patients with different peripheral vestibular diseases.

fected ears in patients with unilateral lesions, however, showed values agreeing with those obtained from normal volunteer subjects.

Fig. 2 presents graphically the mean caloric responses of fourteen patients with unilateral Menière's disease. Here the responses of the affected ear show a decrease in the maximum nystagmus and vertigo while the maximum laterotorsion remains unaffected. The responses of the nonaffected ears yielded figures not distinguishable from those of the normal individuals.

Fig. 3 presents a similar study of the effects of central lesions. The striking change in the caloric responses of patients with meningo encephalitis is the reduction in the amount of laterotorsion. There is also an indication of increased vertigo, while the nystagmus remains about the same as in normals.

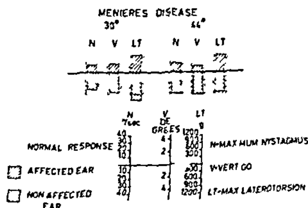


Fig. 2. Graphic representation of mean nystagmus, vertigo and laterotorsion in caloric reactions of 14 patients with Ménière's disease.

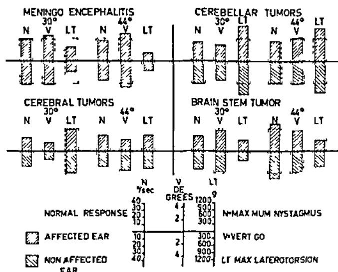


FIG 3 Graphic representation of mean nystagmus vertigo and laterotorsion in caloric reactions of patients with different central diseases

In patients with neoplasms of the brain cerebral tumors seem to reduce all three reflexes moderately In the cerebellar tumors however there was a more marked increase in laterotorsion The isolated case of pontine tumor presented a picture of normal vertigo but decreased nystagmus and laterotorsion There was a spontaneous vertical but no horizontal nystagmus and a pathological spontaneous laterotorsion

DISCUSSION

The impulses travelling from the labyrinthine cristal and macular receptors to the effector muscles of the eyes and of the head trunk and extremities are subjected in the brain to facilitatory and/or inhibitory influences The reticular system (10) the cerebellum (1) and other parts in the brain are involved in this modulation of impulses (2 3)

Electro nystagmography and the pneumatic device for recording laterotorsion have made it possible to record the reflex movements of the ocular and spinal muscles in response to caloric stimuli

Since these reflexes are usually accompanied by vertigo an attempt was made to have the patients evaluate this symptom Their estimates using the scale of Lidvall (9) seemed fairly adequate as they also correlated with objective autonomic symptoms such as perspiration and vomiting

A study of the patterns of behaviour of nystagmus and laterotorsion in normals showed that the maximum of each is reached at different times that their durations differed and that no quantitative correlation between these two reflexes could be found (8) This lends suppport to the hypothesis that there may be different central modulations on the pathways for the cristo

ocular and cristo spinal reflexes (10) This conception was strengthened by our findings of six different patterns of vestibular reactivity (see Table 2)

I Peripheral lesions whether caused by vestibular neuronitis acoustic neurinoma oto toxic damage or congenital defects showed a decrease in both nystagmus and laterotorsion as well as in vertigo (see Fig 1)

In these lesions the three qualities nystagmus vertigo and laterotorsion show a quite parallel decrease This indicates a lesion to the *receptor organ or to its nerve*

II In the Meniere cases the decrease of nystagmus and vertigo was not paralleled in the laterotorsion which showed *no significant deviation* from normal values The pathophysiological background for this difference is difficult to conceive but two suggestions might be made (1) In these Meniere cases a normal caloric stimulus must be expected to cause a diminished input to the brain because of the hydrops in the labyrinth This diminished input is reflected in the reduced nystagmus and the reduced vertigo The vestibulo spinal impulses however seem to be facilitated at the relay nuclei resulting in the usual laterotorsion response (2) The difference in behaviour between nystagmus vertigo and laterotorsion in Meniere cases could also be explained in an entirely different way If the cristo ocular reflex originates in certain sensory cells on the crista and the cristo spinal reflex in other cells on the same structure a greater resistance to the hydrops of the receptors for cristo spinal impulses would also explain the persistence of the laterotorsion in Meniere cases

III In order to check whether diffuse central nervous tissue changes would actually affect the central vestibular pathways cases of meningo encephalitis with vertigo were studied The resulting pattern of behaviour of the reflexes in these cases was found to be completely different from that of the peripheral lesions or of Meniere's disease (see Fig 3 and Table 2) The significant decrease in laterotorsion was not paralleled by changes in nystagmus The vertigo was increased from the normal mean of 3 2 to 3 7 which however is not a statistically significant difference In these cases of meningo encephalitis lesions within the brain must be held responsible for the different modulations of the two reflexes

IV V and VI An attempt was made to see if the local destruction of tumors could be used for further elucidation of the changes in vestibular reactivity pattern For this study a rough division was made into cerebral cerebellar and brain stem lesions It is realized that the number of cases is adequate only as an indication whether some differently localized brain tumors produce different patterns of labyrinthine reflex behaviour If so a study of many more cases will be necessary to confirm this variation in patterns for future clinical use

Examination of Fig 3 shows that while there is a general decrease in activity of all properties in the cerebral tumor cases the cases with the cerebellar neoplasms caused a decrease in nystagmus and vertigo but an increase in laterotorsion A brain stem tumor presented still another picture in which

the decrease is limited to the laterotorsion in a manner somewhat similar to what is found in meningo encephalitis Subdivision of the cerebral tumors again looked promising but reduced the numbers to such small quantities that evaluation becomes speculation

The variation in the central influence on vestibular pathways with different lesions is in good agreement with results from experimental work in electro physiology by Gernandt & Gilman (3) who found a definite modulation on vestibular impulses caused by influence from the central nervous system

The clear cut separation of patterns of vestibular behaviour with various pathological conditions offers tools for work in at least three directions (1) for improving clinical oto neurologic diagnosis (2) for elucidating the physio logical effects of different brain areas on labyrinthine pathways (3) for studying the mechanism of drug actions on various parts of the brain

ZUSAMMENFASSUNG

Eine vergleichende Untersuchung uber kalorischen Nystagmus Vertigo und Laterotorsion wurde an Normalpersonen und Patienten mit peripheren Labyrinthla sionen Mb Meniere, Meningo encephalitis und Gehirntumoren ausgefuhrt

Bei den verschiedenen Schadigungen wurden Abweichungen in der Reaktionsweise gefunden Beim Mb Meniere z B nahm die kalorische Erregbarkeit des Nystagmus und des Vertigo ab, wahrend die Laterotorsion normal blieb Dagegen zeigte die Meningo encephalitis eine normale Erregbarkeit des Nystagmus, aber eine Abnahme der *Laterotorsion*

Dies veranlasste uns die Hypothese zu diskutieren dass cristo oculare und cristo spinale Reflexe verschiedene Mechanismen haben durch welche sie trotz gemein samen Ursprunges ihres Reizes moduliert werden Es wurde auch die Moglichkeit verschiedener Rezeptorzellen und Neurone fur die cristo ocularen und cristo spinalen Reflexe erortert Eine grossere Widerstandsfahigkeit der Einheiten die am vestibulo spinalen Reflexe beteiligt sind wurde dann auch die normale kalorische Laterotorsion bei Fallen von Mb Ménière erklaren

Eine orientierende Untersuchung an Gehirntumoren deutete darauf hin dass verschiedene Lokalisationen der Tumoren ein verschiedenes Verhalten von Nystag mus Vertigo und Laterotorsion verursachen

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THE NORMAL HUMAN INTRA AURAL MUSCLE REFLEX IN RESPONSE TO SOUND

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1 The particular modification of the method of tympanomanometry as it is employed in our laboratory has proven to be a useful tool in the investigation of the normal human intra aural muscle reflex

2 Some of the signal response relationships of this reflex have been investigated and discussed

3 Evidence was presented which supports the thesis that both the stapedius and tensor tympany muscles in the human respond to sound stimuli

4 The suggestion is made that this technique lends itself to increasing the accuracy of pre operative diagnosis of some forms of conductive hearing loss

INTRODUCTION

In recent years information processing in the nervous system in general and in the auditory system in particular has pre empted the interest of our laboratory The understanding of the function of the middle ear interposed as it is between the source of an acoustic signal and the cochlea is of vital importance when one attempts to define the actual input to the cochlea This report will deal with a series of investigations on the activity of the middle ear muscles *in response to sound* An attempt was made to define the relative roles of the stapedius and tensor tympany muscles in the intra aural reflex and to relate their participation to the parameters of the acoustic signal The particular modifications of the method of tympanomanometry used are described stress being placed on the simplicity of instrumentation and the high degree of sensitivity attained It is to be noted that the first portion of the report deals with the results obtained using a tympanomanometric system with AC response characteristics thus limiting the information to the description of the threshold properties of the reflex as a whole The second phase describes the results obtained with an improved DC electronics system and deals with the time amplitude history of the intra aural muscle reflex

METHOD

Part I

As a technique for measuring the reflex in a normal human subject we have used the method of tympanomanometry It is to be noted that this method takes advantage of the consensuality of this reflex permitting acoustic



FIG 1 Apparatus as it appears during testing procedure Plug unit in place connected to Altec 21C microphone by length of polyethylene tubing Insert demonstrates plug unit

stimulation of one ear and reflex measurement on the contralateral ear The ear in which the reflex was to be measured was hermetically sealed with a molded soft plastic insertion type ear plug V 51R For the test the plug was pierced through the center by a stainless steel tube with a collar at one end A second collar was slipped over the steel tube and firmly held the plug forming a tight seal (Fig 1) The fully assembled unit is light in weight and easily held in place As a pressure transducer for measuring the pressure changes in the sealed external canal we used a capacity type microphone Altec 21C fitted with a probe tube and connected to the tube of the plug unit by a length of polyethylene tubing (Fig 1) The frequency response of the system was down 6 db at 250 cps and at 1/3 cps e g an AC coupled system Tests were conducted in an anechoic chamber An Altec Lansing *speaker was used to deliver undistorted free field signals up to about 115 db* ref 0 0002 dynes/cm² to each subject A second microphone (W E 640AA) at the subject's unplugged ear monitored the acoustic signal and the output of both microphones was displayed on a split beam oscilloscope For the purpose of permanent records the face of the oscilloscope was photographed The sensitivity of the system is limited only by the electronic noise level of the Altec microphone and complement in this case about 60 db ref 0 0002 dynes/cm² Pressure changes measured at this limit of sensitivity are calculated to be in the region of 1.5×10^{-4} mm of Hg If this value is translated into terms of displacement of the tympanic membrane *it is found to be* equivalent to about 1×10^{-6} cm Fig 2 depicts the time amplitude envelope of the signals used Time (in ms) is given in terms of rise time duration of constant amplitude phase and decay time (e g 10 80–10) These values are

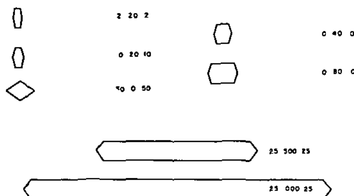


FIG 2 Schematic diagram of acoustic stimuli tested Time scale in milliseconds of rise time, constant amplitude phase and decay time

confirmed from the output of the signal monitor microphone (640AA) at the subject s ear The pure tones were 400 800, 1600 3200 and 6400 cps In addition the signal 50–0–50, was also presented as banded noise with center frequencies as above and band widths approximating those given by Fletcher (1953) as critical bands Fig 3 is an example of our method of recording data In the absence of sound stimuli the regular perturbations in the pressure trace are coincident with the subject s heart beat The origin of this pressure pulse is unknown With the onset of sound stimuli the pressure fluctuations coincident with the reflex response are seen superimposed on the pulse trace The system is set up so that a downward deflection is

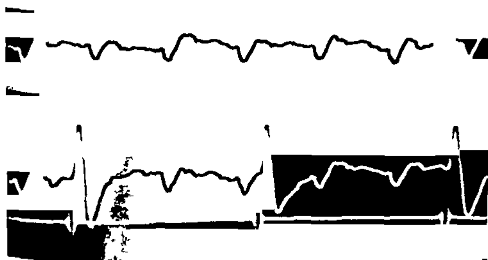


FIG 3 Example of data record using AC system Top pair of traces demonstrates the periodic pressure pulse fluctuations in the sealed external auditory canal in the absence of acoustic signal Bottom pair of traces demonstrates the reflex in response to an acoustic signal superimposed on the pulse trace

inscribed by an increase in pressure This is a typical biphasic trace recorded with this AC system

We were of course aware that a severe limitation on interpretation of the time history of the reflex response was imposed by the lack of DC capabilities of the system The questions which we might hope to answer had to be tailored with this limitation in mind The first experiments utilizing this system were designed to answer the following questions (1) In what portion of normal young adults can the onset of an intra aural muscle reflex in response to sound be demonstrated? (2) Within the limits of the sensitivity of the system what are the threshold values for the reflex? (3) In what way is this reflex threshold effected by the subject's threshold of detection and the parameters of the signal?

Tests were conducted on a group of male university students screened at the outset to include only those with normal audiograms and no evidence of middle ear disease A panel of ten was finally chosen consisting of only those students whose reflex could be elicited by the majority of the signals to be used (Fig 2) at intensity levels below the 115 db limitation of our system The signals were presented to each subject monaurally at a random rate not exceeding 2/second In addition each subject was required to make a sensation threshold decision on the basis of not more than 24 repetitions of the signal

Part II

In order to consider problems concerned with the true time history of the reflex we changed from the Altec microphone (pressure transducer) to a Western Electric 640AA and changed to DC/FM electronics so that we could now record the true time history of the pressure changes in the external canal Applied DC pressure loads negative or positive (tested up to 20 mm of alcohol) could be maintained for periods up to 15 minutes or longer As a recording device we changed from the oscilloscope to a Computer of Average Transients (CAT — Mnemotron Corp) With this instrument we could now record the average response to multiple stimuli and thus come closer to an accurate picture of the reflex

Fig 4 demonstrates the typical format of what we shall refer to as a CAT recording Each figure is labeled as to the total time during which the CAT records information i e analysis time and the series of 20 dots on each trace gives time intervals in terms of the total analysis time In the first trace the analysis time is 32 seconds and therefore the time between dots is 1 6 seconds The system is set up so that a positive pressure inscribes an upward deflection The first trace represents a single sweep of the CAT during which time a positive pressure was applied in the system It is at once obvious that the DC pressure change is maintained for at least 16 seconds Such a DC check was made before and after each test period The other two figures represent a negative and a positive pressure response to similar signals in different subjects These are typical responses in their general



FIG 4 Typical record from Computer of Average Transients (CAT) Positive pressure in the sealed external auditory canal inscribes an upward deflection Time proceeds from left to right Equally spaced time markers divide total analysis time into 20 equal intervals First trace Single sweep of CAT, analysis time of 32 seconds Represents DC response of system to a positive pressure of 10 mm alcohol during last 16 seconds of record Second trace D [illegible] CAT record average of 100 responses (× 100) analysis time of 2 seconds signal 1600 cps 40 1[illegible] 4[illegible] Typical response of a predominantly negative pressure reflex Third trace J C CAT record [illegible] 100 analysis time of 1 second Signal 1600 cps 40 500 40 Typical response from another subject of a predominantly positive pressure reflex

shape but are atypical in the presence of rather large and regular oscillations the first at a rate of about 3 5/second and the second at 8 5/second

RESULTS

Part I

Only about 5 % of the original group of 30 subjects tested did not respond to the signals presented with a measurable acoustic reflex Of the 95 % remaining about 75 % did respond to the majority of the signals at levels well below the 115 db limitation of the system Ten of the latter subjects formed the panel used in the experiment

It was clearly demonstrated that each subject had a characteristic reflex threshold Fig 5 demonstrates the reflex and detection (sensation) level thresholds for the single signal 50 0 50 individually plotted for each member of the panel The reflex thresholds were repeatable within 1 db during the same period However from week to week variations as much as 5 db were recorded Fig 6 (A and B) depicts the average response of a panel of ten subjects to the battery of signals The signals have been grouped according to increasing acoustic energy[1] Group I the least power is composed of 2 20 2 10 20 10 and 50 0 50 Group II is composed of 10 40 10 and 10–80 10 Group III the greatest power is composed of 25 500 25 and 25 1000–25 When classified in this way it was demonstrated that threshold values for members of the group were not significantly different The

[1] Acoustic energy per unit area $\left(\frac{\text{watt sec}}{\text{cm}^2}\right)$ [illegible] 10^{-8} [illegible] 10^{-8} [illegible]
I = RMS amplitude [illegible] duration seconds

I	II	III
2 20 2 [illegible]	10 40 10 [illegible]	25 500 25 [illegible]
10 20 10 [illegible]	10 80 10 [illegible]	25 1000 25 [illegible]
50 0 50 [illegible]		

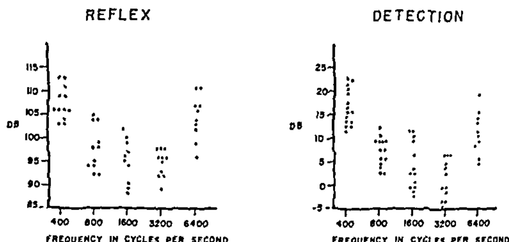


FIG 5 Individual threshold values for members of the panel in response to signal 50-0 50 Signal amplitude in db ref 0 0002 dynes/cm²

values at detection level, for the 500 and 1000 ms signals, are identical and agree with the accepted free field values for just detectable monaural thresholds The shapes of the two sets of curves, reflex and detection, are remarkably similar both as a function of signal frequency and signal envelope Within the range tested, the higher the detection threshold, the higher the

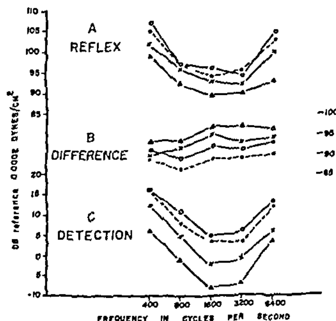


FIG 6 Average response of panel members to acoustic signals at reflex threshold (A) and at detection or sensation threshold (C) Signals are grouped according to increasing acoustic energy ○ group 1A 50 0 50 2 20 2 10 20 10 ● group 1B = 50-0 50 with banded noise × group 2 = 10-40 10 10 80 10 Δ group 3 = 25 500 25, 25 1000 25 The family of curves in B represent the average reflex threshold in db above sensation level e g A-C = B

reflex threshold Most importantly, there appears to be a relation between the total length of the signal and its intensity with regard to its ability to reach both detection and reflex thresholds That is the longer the signal remains on the less amplitude it need develop to reach threshold There apparently is a limit to this phenomenon since prolongation of the signal beyond 500 ms does not lower either threshold When the same information is plotted on one graph (Fig 6*B*) as the difference between reflex and detection thresholds it is to be noted that the curves approximate a horizontal line The average reflex threshold is about 92 db+4 db sensation level That is regardless of the frequency or the shape of the signal the reflex threshold is about 92 db above the specific detection threshold

Before going on it is necessary to mention a few points First to bring attention to the 5% of subjects with apparently normal ears whose reflex could not be demonstrated at stimulus levels up to 115 db Secondly to mention the ancillary findings that in well trained subjects the contraction of the intra aural muscles in response to sound stimuli can be heard by the subject himself If the subject is permitted to control the intensity of the signal and is asked to determine his own reflex threshold using the disappearance of the sound of the muscle contraction as an end point it is consistently found that this value is within 1 db of the threshold determined by visually monitoring on the scope the pressure changes in the same ear And lastly to call attention to the fact that the pressure change in the external canal in response to sound has been found to vary from subject to subject In some the change is a negative pressure and in others it is a positive pressure

Part II

Using the modified system which provided DC recording capabilities the first thing checked was the relative sensitivity of the AC system and the validity of the threshold information obtained up to this point By averaging the response to 100 stimuli (indicated on each trace as ×100) we could now improve signal to noise ratio by 10 to 1 or about a 20 db increase in sensitivity Using this method the reflex thresholds were lowered less than 3 db thus lending confirmation of the threshold values presented so far The remainder of the report will concentrate on the time course of events of the reflex as a function of the particular acoustic signal

Fig 7 demonstrates in two subjects the effect on the time course of the reflex response of gradually increasing the total duration of the stimulus without changing its intensity Each signal has a rise time of 50 ms and a plateau varying from 0 to 200 ms The RMS sound pressure level was 100 db for each signal Each figure represents the average of 100 responses Here again *it may be seen that signal duration alone may effect reflex response* At levels above threshold the reflex response increases in amplitude as the signal length is prolonged while holding signal amplitude constant until about 200 ms when further signal prolongation simply lengthens the response

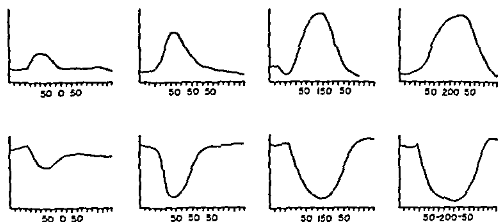


FIG 7 Reflex response to increasing signal duration without changing signal amplitude (100 db) CAT record × 100 analysis time of 0 5 second Signal 800 cps Time amplitude envelope of signal given under each trace Top group D D Reflex response demonstrates pos tive pressure change Plateau of response begins to appear w th total signal duration of 250 ms Bottom group D F Reflex response is predominantly a negative pressure change and also forms a plateau when total signal duration reaches 250 ms

but adds no amplitude The evidence presented so far confirms the well known temporal integration occurring at sensation threshold and suggests that a similar mechanism might be operative in the reflex both at threshold levels and above

Up to this time the time amplitude envelope of the signals has been either triangular or trapezoidal In order to test the reflex response to a linear increase in signal amplitude it was necessary to change to a signal whose amplitude increased linearly over a relatively long period of time The signal used was a ramp with approximately a 40 db linear increase in sound pressure level a duration of either one or two seconds followed by an abrupt cut off In Fig 8 it is seen in two different subjects that if the peak amplitude of the signal is close to reflex threshold then the reflex is in operation for only the very last portion of the stimulus and never reaches a very great amplitude On the other hand if the peak value is more than 10 or 15 db above threshold then the reflex reaches its zenith very early and in essence remains pinned for most of the duration of the stimulus However if the peak amplitude is set at some intermediate value it may be demonstrated that the reflex will begin early increase linearly with the signal amplitude and reach its own peak just after the signal turns off (It should be noted that in this series the signal turns off at the tenth time marker on each trace) A close examination of these traces indicates that the span of linear response of the reflex is about 18 db Note that this does not indicate that the reflex provides 18 db of attenuation or protection but implies that if the reflex function is in part a protective one then it can probably perform linearly in this capacity over at least an 18 db range above its threshold The relatively steep slope of the trace after the sound is turned off and the tendency

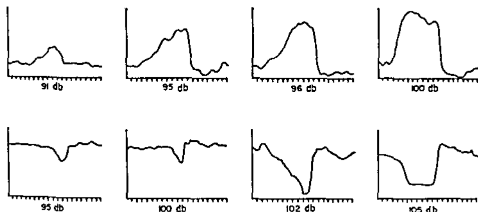


Fig 8 Reflex response to ramp function total signal duration of 2 seconds and total analysis time of 4 seconds Final amplitude reached by ramp is noted under each trace CAT record 50 Signal 800 cps Ramp signal has linear increase in amplitude over range of about 40 db Top group H W Predominantly positive pressure response of subject to ramp signal Note the linearity of the pressure curve when the peak of the signal is 95 db Bottom group D F Negative type pressure response to the same signal configuration Note again the linear response in this case when the signal peaks at 102 db

to proceed below the equilibrium point are characteristics of the response commonly seen using this signal shape Note that the response to this signal configuration is similar whether the pressure change is predominantly positive pressure or negative

Up to this point we have limited ourselves to a description of the intra aural muscle reflex as a unit we have declined to recognize its component parts the stapedius and tensor tympani muscles So far we have defined for this unit threshold values relation of signal intensity and duration in its effect on the reflex response the DC capability of the response and lastly the ability of the reflex to respond linearly over a defined range A thorough search of the literature will convince the reader that the problem of whether or not the tensor tympani muscle responds to acoustic stimuli in normal humans has not been solved The stapedius muscle does respond to acoustic stimuli *in animals* and in man (Wersäll 1958) *The tensor has been seen to* behave similarly in some animals Without laboring the issue it is fair to say that a large group of investigators hold that in the human only the stapedius muscle responds to acoustic stimuli (Klockhoff 1961) The first indication that we might have evidence for the action of both component muscles in response to sound was of course the fact that we early demonstrated both negative pressure and positive pressure changes as a response to acoustic signals a situation difficult to explain on the basis of a single muscle reflex However the most suggestive evidence developed when we began using the ramp signal The good possibility existed that the plateau effect was occasioned by the beginning contraction of a second antagonistic muscle that the oscillations occasionally seen were the effects of the two

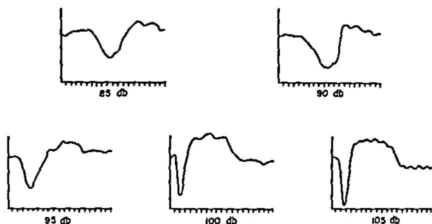


Fig 9 Demonstration of conversion of monophasic negative pressure response to biphasic response by increasing signal amplitude CAT record ×50, analysis time 2 seconds 800 cps, 1 second ramp signal

muscles pulling against each other, that the rapid return of the pressure trace to and then below the equilibrium point (quite unlike the relaxation of a single muscle) was the result of the unopposed action of the antagonist and the subsequent gradual return to baseline, a typical relaxation of a single muscle One other point may be mentioned here perhaps the reason for the existence of that 5 % of subjects in whom no reflex could be demonstrated, is that in these few subjects, the two component muscles have very nearly the same thresholds and contract with nearly equal strength so that the resultant displacement of the tympanic membrane, in these cases, was so small as to be below the level of detectability of our system A more obvious display of the action of the two muscles may be seen in Fig 9 In this case near threshold level a stimulus elicits a negative response with a slow return to baseline As the signal is increased in loudness, less and less of the total response is formed by this negative response By the time the signal has increased by 20 db, the major portion of the response is taken up by the positive deflection Note the oscillations mentioned previously In the past it has been suggested that the stapedius muscle can move the tympanic membrane outward and create a positive pressure in the external canal Certainly, it is difficult to see how the tympanic muscle could do anything but pull the membrane inward, and produce a negative pressure The results presented seem to indicate that both these statements are true

The final answer to these questions lies in the examination of patients with only one functional muscle Much difficulty is encountered in this attempt since most patients we have examined have had bilateral disease and it was impossible to deliver enough sound to the contralateral ear to be sure we were above the consensual reflex threshold levels In Fig 10 the first trace is the average response to 100 acoustic stimuli of a patient without a stapedius muscle (post stapedectomy for otosclerosis) and demonstrates the



FIG 10 First trace Negative pressure reflex in 53 year-old male post stapedectomy CAT record × 100 1 second analys s time 800 cps 40 60–40 Middle trace Negative pressure response in 40-year-old male *pre-operative Operative D agnosis severe stapes f xation CAT recording* × 100 1 second analys s time 1600 cps 40–60–40 Last trace B phasic pressure response in 28 year-old male pre-operative diagnosis of otosclerosis Operat ve diagnosis of no m ddle ear disease CAT record × 100 1 second analys s time 1600 cps 40–60–40

negative pressure response of the remaining tensor tympani muscle The second trace is the response of a patient to sound stimuli before operation for otosclerosis At operation the stapes was completely fixed in oval win dow and the stapedius muscle intact a situation which precluded the normal function of the latter muscle The response is again negative characteristic of the unopposed action of the tensor tympani muscle

The last trace is from a patient with a preoperative diagnosis of oto sclerosis The obvious biphasic activity demonstrated in this preoperative test mitigated against the diagnosis At operation there was no demonstrable middle ear disease This phase of this investigation i e aid in clinical diagnosis is one that should be explored further

ZUSAMMENFASSUNG

1 Die spezielle Abanderung der tympano manometrischen Methode wie sie in unserem Laboratorium verwandt wird hat sich als ein brauchbares Hilfsmittel zum Studium der normalen Mittelohr Reflexe am Menschen erwiesen

2 Beziehungen zwischen dem akustischen Reiz seiner Amplitude und Zeitfunk tion und dem Reflex werden untersucht und diskutiert

3 Es werden Ergebnisse berichtet welche die Ansicht unterstützen dass sowohl der stapedius wie auch der tensor tympani Muskel beim Menschen auf Schallsignale ansprechen

4 Es wird vorgeschlagen dass die angewandte Methode sich gut dazu eignet die Zuverlassigkeit einer prae operativen Diagnose bei gewissen Formen von Mittel ohr Gehorschaden zu erhohen

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EFFECTS OF VISUAL EXPERIENCE ON VESTIBULAR NYSTAGMUS HABITUATION IN THE CAT

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Separate groups of ten cats each were exposed to three specific varieties of visual experience during a series of angular accelerations and then compared on a test trial in darkness with three control groups of ten cats each that had received the same acceleration experience but without concomitant visual stimulation Animals were maintained in a high state of arousal with *d* amphetamine Electro oculographic recordings showed that the nystagmic response decrement was prominent for all six groups and that the visual experience neither hastened nor slowed the habituation process

With repeated testing of man in total darkness at moderate acceleration values a marked reduction in the nystagmic output does not occur if the level of alertness is controlled (Collins 1962 Wendt 1951) But a similar trial series will greatly reduce the output of a cat (Crampton & Schwam 1961) Although this dissimilarity in findings may be attributable to fundamental factors related to the differing taxonomic orders there are at least two possible causes which are experiential in nature One is that adult man has already been exposed to a wide range of accelerative stimuli and that the initial habituation has already been established Further testing at only moderate levels is not sufficient to produce a further habituation Cats on the other hand are inexperienced in respect to all unusual accelerations and therefore display a rapid habituation with the very first trials There is fair evidence that this pre exposure of man and thus pre habituation accounts for the difference For example nystagmus is reduced among members of those occupations which entail high or unique accelerations dancing (Mowrer 1934) figure skating (McCabe 1960) or piloting fighter aircraft (Aschan 1954)

The second possibility concerns the importance of vision In these unusual human activities vision is an adjunct to the acceleration experience Perhaps visual stimulation in conjunction with angular accelerations hastens the habituation process and the marked nystagmic habituation seen in members of these special occupations is in part due to the concomitant visual stimulation

When vision is permitted during the usual Barany chair examination in which the subject is braked to a stop from a high angular velocity a decided suppression of eye movements is found Although the human evidence is not

entirely in agreement on this point it is frequently found that this suppression increases with repeated testing. This increased suppression has been attributed to a resolution of the conflict between vestibular and visual control of the eyes (Dodge, 1923a, Wendt 1936, 1951). A related question and the one of particular interest here, is whether vision during rotation will hasten or slow the habituation process if evaluated later with acceleration in total darkness. Two experiments with conflicting findings on this point. Mowrer (1934) found that permitting vision during acceleration trials prevented habituation of pigeon head nystagmus but a recent investigation of man showed that vision may be a necessary variable in the habituation process (Guedry, Collins & Sheffey, 1961).

The purpose of this experiment is to re-evaluate the importance of vision for nystagmus habituation. The cat habituates rapidly during the first several trials and is therefore a favorable animal for evaluating critical variables. If vision is a powerful factor it should produce a large effect. Separate groups were exposed to three specific varieties of visual experience during a series of accelerations and then compared on a test trial in darkness with control groups that had received the same acceleration experience but without concomitant visual stimulation. All animals were maintained in a high state of arousal with *d* amphetamine.

METHODS

The turntable, 1.25 meters in diameter, was driven by a hydraulic pump and motor through a friction wheel on its perimeter. The table was mounted within a radio frequency shielded and light proof room. Physiological signals were led from the turntable through slip rings to the recording equipment in the adjoining room.

At least two days prior to the day of testing each animal was anesthetized and small holes were drilled in the canine teeth for restraint purposes. On the day of testing a 3 mg/kg interperitoneal injection of d amphetamine sulfate was administered 60 to 90 min before the first trial. This drug has been shown to maintain a high arousal level which in turn produces a high nystagmic output (Crampton, 1961). Following the injection the animal was placed in a rabbit box and a taut length of piano wire was strung through the holes in the canine teeth to fix the head by the method and humane method of Henriksson, Fernandez & Kohut (1961). The principles of laboratory animal care detailed by the National Society for Medical Research were observed. Finally the restraining box was mounted on the turntable and the cat's head positioned directly over the rotatory axis with the horizontal canals in the plane of rotation.

The electronystagmogram was picked up by needle electrodes inserted in skin at the outer canthi. A pair of electrodes was inserted in skin on the crown to monitor the electroencephalogram (EEG) and the ground lead was attached to the wire strung through the teeth. All recording was through

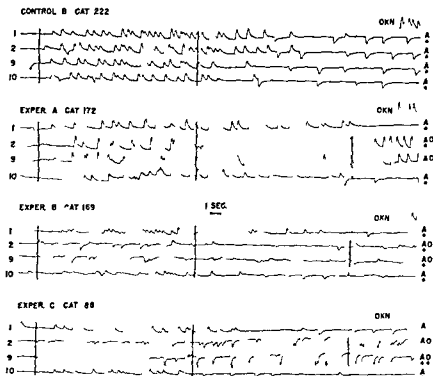


Fig. 2. Examples of nystagmus from trials 1, 2, 9 and 10 for a control cat on schedule B, for experimental cats on schedules A, B and C, and each animal's optokinetic nystagmus at 36°/sec CW rotation. The 15 sec period of acceleration occurred between the heavy vertical lines at the left and those near the center. The direction of the nystagmic fast phase is indicated with arrows: A for acceleration nystagmus and *O* for optokinetic nystagmus. The lights turned on at the onset of acceleration for experimental animals on trials 2 through 9 were turned off 30 sec thereafter at the point indicated in these examples by the short vertical lines.

than on 2, but that habituation is evident when those trials in darkness (1 and 10) are compared. The well developed optokinetic after-nystagmus displayed by this animal and cat 188 is typical for schedules A and C.

The records for experimental group cat 169, tested on schedule B, is of special interest because of the similarity of this schedule to that of the usual Bárány chair examination with the lights on for trials 2 through 9. Note that the after-nystagmus, when at a dead stop, is almost completely inhibited in the trial 2 and 9 examples. During the period of acceleration on these trials the optokinetic nystagmus just overpowered the vestibular nystagmus in trial 2, but by trial 9, the visual control of the eyes was almost complete. Trial 10, when compared with trial 1, shows that the vestibular component had been greatly reduced in the interim trials. Experimental cat 188, tested on schedule C, showed a very similar progression of events. Here again the visual control of the eyes was far more prominent for trial 9 than 2, and the comparison between trial 10 and trial 1 shows a reduction in the vestibular component.

The magnitude of the slow phase primary nystagmic amplitudes was mea-

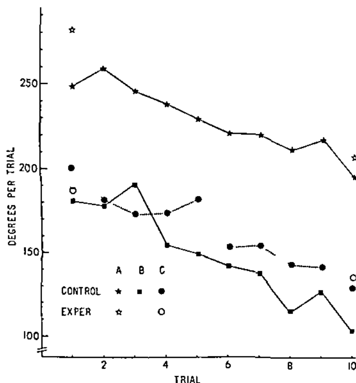


FIG 3 Slow phase primary nystagmus produced on each trial for each of the six groups Each point indicates the average for 10 animals

sured second by second for trials 1 and 10 for each of the three experimental groups All ten trials were measured for the three control groups For each measured trial the primary nystagmus was scored which occurred during the 15 sec of acceleration and the 15 sec of constant velocity immediately there after Recorded slow phase amplitudes were converted into degrees/sec by linear transformation based on the optokinetic response to a 36°/sec rotation of the visual field Finally a total primary nystagmic output value for each trial was computed by adding the second by second measurements The secondary nystagmus was not scored

The trial by trial averages are shown for the six groups in Fig 3 Since schedule A appeared to have produced more nystagmic output for both the experimental and control groups than for schedules B and C a statistical test was performed using data from all ten trials for the three control groups (Table 1) Employing an analysis of variance procedure designed for repeated measures of the same subjects (Edwards 1950) it was found that there was a significant difference between the groups (0 05 level of significance) no significant trials × schedules interaction and as would be expected a significant difference due to trials (0 001 level of significance)

The statistical test of interest is the evaluation of differences in habituation which may be attribut d t the presence or absence of light during trials 2

TABLE 1 *Variance analysis for control groups and difference scores*

Source of variation	*df*	Mean square	*F*
Control groups			
Between schedules A, B, C	2	181 976 0	4 635[a]
Between cats in same group	27	39 909 3	
Between trials 1 through 10	9	15 397 2	18 766[b]
Interaction trials × schedules	18	820 5	—
Interaction cats × trials	243	909	
Difference scores			
Between groups control and experimental	1	1 169 2	—
Between schedules A, B, C	2	316	—
Interaction groups × schedules	2	3 188 5	—
Within cells	54	7 135 1	

[a] 0 05 level of significance
[b] 0 001 level of significance

through 9, or to the three schedules. Difference scores were computed for each of the sixty cats by subtracting the nystagmic output from trial 10 from that of trial 1. An analysis of variance on these difference scores for the two lighting conditions and the three velocity programs was performed (Table 1). No difference in the magnitude of habituation can be attributed to either the *presence or absence of light during trials 2 through 9, or to the three velocity* schedules.

DISCUSSION

The differences in nystagmic output among the three velocity schedules may be due to the differences in the noise and vibration. If cats are tested without *d*-amphetamine, many become drowsy and some may sleep as indicated by EEG recordings (Crampton & Schwam 1961). *d*-Amphetamine reduces the variability due to this factor and insures a high nystagmic output (Crampton 1961). The differences in output among the schedules may indicate that, although a high level of arousal is maintained, a maximum level is not and that noise increases arousal even further. Schedule A was accompanied by an increasing sound level throughout the acceleration. Schedule C was associated with a decreasing sound level during the acceleration. Not only was the sound level decreasing for schedule B during the acceleration but it was at an absolute minimum during the period of constant velocity which was at a dead stop. The fact that the nystagmic output for the three groups, certainly for group A, can be ranked on this basis lends support for the noise explanation of the differences. On the other hand, differences in nystagmic magnitude and duration of this order are often inexplicably found for man between responses to periods of increasing velocity and decreasing

velocity, although the accelerations are identical (e g Collins 1962 Collins Crampton & Posner, 1961) Fortunately the trial × schedules interaction here is not significant (Table 1) and the difference scores analysis is valid in spite of the inadequately explained variation among schedules

The prominence of visual over vestibular control of the eyes was described for man by Dodge (1923*a* 1923*b*) Wendt (1936 1951) concluded that if the level of alertness is controlled habituation of nystagmus is due to an increase of visual control with repeated testing and held that the vestibular component itself does not undergo a reduction Optokinetic nystagmus without associated vestibular stimulation sometimes improves in quality with repeated testing and this improvement would contribute to the elegance of visual control in the later trials much as Wendt concluded But these data from cat show that the ascendency of vision appears to be largely because of the selective reduction or habituation of the competing vestibular component an interpretation that is supported by the absence of differences in habituation among the groups receiving interposed visual experience and the control groups Since visual stimulation neither hastens nor slows the habituation process the implication is that the reduced nystagmus found in members of certain special occupations is due to the accelerative experience alone A specific experiment with man is required before accepting this generalization

General comment

Much of the confusion in terms employed when describing the habituation process has arisen because the complexity of the phenomenon has not been fully appreciated Response decrement (RD) introduced by Hood & Pfaltz (1954) is an excellent generic term in that it describes the phenomenon without a commitment to any single causative factor It now appears that a reduced vestibular response produced by any one of at least four factors visual suppression arousal habituation sensory adaptation and acceleration (to include habituation to caloric irrigation) Additional factors may be identified in the future When discussing response decrements it is necessary to indicate the stimulus parameters the experimental animal and the response—ocular nystagmus oculogyral illusion or subjective judgments of velocity The greater portion of the conflict among findings concerning habituation can be attributed to a confounding of the action of the underlying factors and to inadequate stimulus specification

Visual suppression of vestibular nystagmus is a common finding and a prominent feature of the data described here Although these results indicate that the presence of vision during rotatory trials does not alter the rate of habituation if later evaluated by a test in darkness it must be emphasized that this applies only to nystagmus The amount of visual experience is an important variable when evaluating habituation of the oculogyral effect in man (Brown & Guedry 1951) and vision is known to affect nystagmus and subjective reactions differently (Guedry *et al* 1961)

Nystagmic output is very dependent upon the level of arousal or alertness. A high state of arousal occasions a high nystagmic output, a fact confirmed for both cat (Crampton & Schwam 1961) and man (Collins *et al* 1961). Arousal reactions are known to habituate to repeated, monotonous stimuli and, further, to show a symmetrical generalization gradient. Specifically, either an increase or decrease in frequency from that of an often repeated tone will elicit arousal according to the magnitude of the stimulus change. This was first described by Sharpless & Jasper (1956) and later examined definitively by Apelbaum, Silva, Frick & Segundo (1960). Arousal states have a profound influence on sensory activity, for example, on olfactory bulb activity (Hernandez-Péon, Lavin, Alcocer-Cuaron & Marcelin 1960), on auditory evoked potentials (Huttenlocher 1960) and on vestibular related neural units in the reticular formation (Duensing & Schaefer 1957). As tempting as it may be to attribute all of the decrement in nystagmic output with repeated testing to this arousal factor, it is known that not all of the nystagmic decrement in cat can be recovered by inciting a high arousal (Crampton & Schwam 1961). And acceleration habituation occurs even when an animal is maintained continuously in a high state of arousal with *d*-amphetamine (Crampton 1961). These are the facts which led to a conclusion that there is an acceleration habituation that is independent of variations in arousal level.

Sensory adaptation refers to the decrement in sense organ sensitivity during an extended application of a suprathreshold stimulus. The sense organ rapidly returns to its initial sensitivity following stimulus relief. Adaptation has been found with single fiber recording from the elasmobranch vestibular nerve in d.c. polarization experiments (Lowenstein 1956), but there is no clear evidence that sensory adaptation is reflected in human nystagmus or subjective reactions. The decline in these responses during prolonged accelerations may be entirely due to a concomitant reduction in alertness induced by the extended and monotonous stimulus (Collins & Guedry 1962). In any event, sensory adaptation is a short term change when compared with the long duration characteristics of acceleration habituation (Fearing 1940).

All facts point to a central locus for acceleration habituation and argue against a peripheral sense organ fatigue explanation. With caloric irrigation a reduced nystagmus will be elicited by stimulation of an untested ear following a long habituation stimulation series in the other ear (Henriksson, Kohut & Fernandez 1961). A central interpretation is further supported by findings indicating that barbiturate anesthetized animals do not habituate (Fearing & Mowrer 1934, Hood & Pfaltz 1954). The possibility that the vestibular efferents (Gacek 1960) play an important part is as yet untested.

With vision depreciated as a factor in nystagmus acceleration habituation the possibility remains that in order to produce a reduction in either cat or man one must employ accelerations at a higher level and/or longer duration than those to which the subject is accustomed. This would account for the

ineffectiveness of moderate accelerations in producing a further acceleration habituation in adult men and the ease with which similar accelerations produce a nystagmic decrement in inexperienced cats An asymmetrical rather than a symmetrical generalization gradient is predicted, but further observations are needed to establish the validity of this interpretation

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ZUSAMMENFASSUNG

Katzen, jeweils 10 in einer Gruppe, wurden drei spezifischen visuellen Reizen während angularer Beschleunigung ausgesetzt und dann in Dunkelexperimenten mit Katzen verglichen, die denselben angularen Beschleunigungen ohne gleichzeitige visuelle Reize ausgesetzt worden waren Die Tiere wurden mit *d* Amphetamine im Zustand hoher Erregung gehalten Die nystagmischen Reaktionsdekremente waren in allen 6 Gruppen ausgesprochen die visuellen Reize jedoch weder beschleunigten die Gewohnung noch verlangsamten sie

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MECHANISMS OF MOTION SICKNESS AS REFLECTED IN THE VERTIGO AND NYSTAGMUS RESPONSES TO REPEATED CALORIC STIMULI

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In the routine caloric test a group of seamen who stated that they practically never had been motion sick had vertigo and nystagmus responses of lower average intensity than those of a group of seamen who asserted that they were somewhat troubled by a tendency to become motion sick

Those subjects who had distinct vertigo responses and normal nystagmus responses at the routine test were selected for a study of the responses to repeated identical monolabyrinthine caloric stimulations In both groups there was habituation in the vertigo and in the nystagmus responses and the habituation curves were approximately parallel

The vestibular mechanisms which are known to be of importance in the development and persistence of motion sickness are discussed It is concluded that the group difference observed in the routine caloric test is probably due to a difference in the sensitivity of the labyrinthine sense organs

INTRODUCTION

At least since the time of the first world war it has been known that individuals who easily become motion sick differ in their responses to experimental labyrinthine stimulations from those who are more resistant to the stimuli of motion sickness

Fisher (1917) considered that rotatory and caloric tests were valuable in determining individual resistance to stimuli that usually evoke motion sickness He found that the less the resistance the more intense and disagreeable the responses He also noticed that the responses to successive labyrinthine stimulations usually showed a progressive decline and suggested that persons should be accustomed to dosed experimental stimulations in order to become more resistant to the stimuli of motion sickness e g before making a sea voyage

van Wulfften Palthe (1922) subjected aviators to rotatory stimuli and observed that if repeated testing elicited a progressive increase in the duration of the nystagmus then there was an impending danger of motion sickness at the next flight

These investigators lacked the technical possibilities of recording with a high degree of precision their interesting observations It was not until the

1930s that more accurate methods were available for the successful exploration of these problems

de Wit (1953) performed cupulometry on a number of seamen and found that the majority of those who had a marked tendency to become motion sick had a steeper sensation cupulogram and a lower perception threshold than those who seldom or never became motion sick

Aschan (1954) studied the sensation and nystagmus cupulograms of aviators and found that flight training lowered the inclination of the curve and increased the threshold value. When there were intervals of some months between the flights the aviators' cupulograms had the same appearance as those of people in general

Preber (1958) performed routine caloric tests according to the Fitzgerald & Hallpike (1942) method on various groups of subjects with well known differences in their tendency to become motion sick. He found that some of the groups showed statistically significant differences both in the duration of vertigo and in the maximum eye speed in the slow phase of nystagmus (recorded according to Henriksson 1955). To my knowledge this is the only detailed study of caloric responses with special regard to motion sickness. The main purpose of Preber's study, however, was to elucidate the relation between certain vegetative responses and the vertigo and nystagmus responses to labyrinthine stimulation and it contained no discussion of peripheral and central vestibular mechanisms

The aim of the present paper is to analyse the responses to the routine caloric test in relation to certain vestibular mechanisms that are known to be of importance in the development and persistence of motion sickness with special reference to the process of habituation

MATERIAL AND METHODS

The experiments were performed on students at the Navigation School in Stockholm. All the subjects satisfied the following four requirements for selection (1) They considered themselves as healthy (2) Had normal hearing when tested with the Quiet check audiometer (3) Answered all the questions in a neurosis questionnaire constructed by the author (to be described in a later paper) (4) Had satisfactory routine calorigrams from a purely technical point of view

The subjects were placed in two groups *Group A*, consisting of persons with little or no tendency to become motion sick *Group B* consisting of persons with a sporadic tendency to become motion sick especially when going to sea after staying for some time on land

All the subjects were informed in advance that one of the objects of the investigation was to elucidate problems connected with motion sickness and that all individual statements would be treated confidentially. This information was given in order to ensure good motivation and a high degree of reliability with regard to the histories. On an average the subjects had had 3 4 years experience of sea voyages. Usually the investigations were carried out from 3 to 6 months after the sailors had returned from their latest voyage

The experiments were performed on 79 subjects, of whom 43 were in Group A and 36 in Group B The median age was approximately the same in both groups (A 21 6 years, B 21 8 years) The number of subjects in Groups A and B who had had suppurative otitis media was 12 and 10 respectively Nine subjects in Group A and six subjects in Group B had suffered from cerebral concussion The incidence of cerebral concussion in the present material (19 per cent) is about the same as that found by Ekblad (1948) in a population of 21 year old Swedish naval conscripts (21 per cent)

The answers to the neurosis questionnaire showed no statistically significant differences between the two groups

None of the subjects had pathologic nystagmus with their eyes open With the eyes closed, spontaneous or positional nystagmus was recorded electronystagmographically in six subjects in Group A and in three in Group B This nystagmus was usually infrequent, irregular and of a low amplitude

The routine caloric test was performed according to the Aschan, Bergstedt & Stahle (1956) modification of Fitzgerald & Hallpike s test and is the same as that employed in my previous studies on habituation to repeated monolabyrinthine caloric stimuli (Lidvall, 1961*a* and 1961*b*)

All the subjects who fulfilled rigorous demands as regards normality from an otoneurological point of view and who, furthermore, had distinct vertigo responses in the routine caloric test, were given a series of four irrigations of the same ear with water at the same temperature (either 30 0 C or 43 2°C)

These series of identical monolabyrinthine caloric stimulations were given to 24 and 26 subjects belonging to Groups A and B respectively

RESULTS

The Routine Caloric Test

In the majority of cases the responses were fairly symmetrical However, in five subjects in Group A and in two in Group B, the duration of the nystagmus responses to stimulation of the right and of the left labyrinths showed a difference which exceeded 14 per cent of the total duration of nystagmus According to Jongkees *et al* (1962) who used the same method of performing the routine caloric test this difference should be considered abnormal These authors regarded as pathologic a directional preponderance of right or left beating nystagmus which exceeded 30 per cent of the total duration In the present series no subject showed such marked directional preponderance

The responses to caloric stimulation were assessed with regard to four variables duration of vertigo maximum intensity of vertigo total number of nystagmic beats and degree of nystagmic dysrhythmia (see Lidvall 1961*a*)

As is seen in Table 1 the average response intensity was throughout less in Group A than in Group B when comparing the corresponding responses

Table 2 shows that not all the differences are statistically significant (sign test) but it is extremely unlikely that all the differences deviated in the same direction merely by chance

TABLE 1 *Vertigo and nystagmus responses to routine caloric tests in Groups A and B*

The mean responses to corresponding stimuli are always of less intensity in the former group which is composed of subjects with a low tendency to become motion sick

Irrigation	30°C right		30°C left		43°C right		43°C left	
Group (subjects)	A	B	A	B	A	B	A	B
Duration of vertigo	57	78	63	79	50	61	52	64
Max intensity of vertigo	2 9	3 4	3 2	3 7	3 0	3 6	3 0	3 5
Number of nystagmic beats	146	178	146	173	125	148	129	151
Nystagmic dysrhythmia	0 7	0 6	0 7	0 6	0 9	0 7	1 0	0 9

TABLE 2 *Statistical significance of differences between vertigo and nystagmus responses to routine caloric tests in Groups A and B*

Sign test values and significance levels are given ** = 0 01 > P > 0 001 * = 0 05 > P > 0 01

Irrigation	30°C right	30°C left	43°C right	43°C left
Duration of vertigo	2 86**	2 25*	1 91	1 85
Max intensity of vertigo	1 58	2.31*	2 01*	1 48
Number of nystagmic beats	2 40*	2.39*	2 02*	1 81
Nystagmic dysrhythmia	−0 80	−0 91	−1 08	−0 82

The present results support the observations made by Preber (1958) that group differences in the tendency to develop motion sickness are reflected in group differences in the intensity of the responses to the routine caloric test

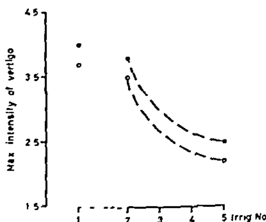


FIG 1 Habituation in vertigo responses to repeated identical monolabyrinthine caloric stimuli ○ = mean values for all observations (n = 21) in group A ● mean values for all observations (n = 26) in group B The first irrigation was carried out as part of the routine caloric test The next four irrigations were performed at 8 minute intervals The habituation curve is outlined between responses Nos 2 and 5

Repeated Identical Monolabyrinthine Caloric Stimuli

The responses to the first and the last irrigations in series of four identical stimulations were assessed with regard to the maximum intensity of vertigo and the total number of nystagmic beats, since these response variables are quite sensitive to habituation (Lidvall, 1961*b*)

As illustrated in Figs 1 and 2, the decline in both the vertigo and the nystagmus responses was approximately parallel in the two groups

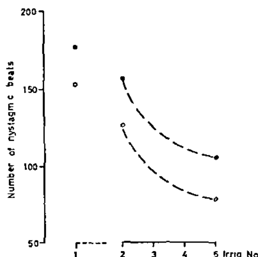


Fig 2 Habituation in nystagmus responses to repeated identical monolabyrinthine caloric stimuli (See text to Fig 1)

DISCUSSION

That individuals with a relatively marked tendency to get motion sick respond, on an average, more intensely to the stimuli of the routine caloric test than do individuals who have a less marked tendency, may be due to at least three different mechanisms (1) labyrinthine hypersensitivity to the stimuli (2) insufficient tonic inhibition of the impulses from the labyrinthine organs and (3) insufficient habituation to the stimuli

Sjoberg (1929, 1931) showed that dogs which have been bilaterally labyrinthectomized do not become motion sick This observation has been confirmed by several other workers It is also well known that persons whose labyrinthine organs or vestibular nerves are non functioning are resistant to the stimuli of motion sickness Therefore it seems only natural to assume that the tendency to motion sickness is in direct proportion to the sensitivity of the labyrinthine organs Unfortunately it may be impossible to use the intact organism for carrying out an experimental study on the effect of variations in the (primary) sensitivity of the labyrinthine organs If labyrinthine sensitivity is influenced, e g by some pharmacological agent the central control is inevitably affected

According to Bauer & Leidler (1912) Hoshino (1921) Pollock & Davis (1927) Dow (1938) Fernandez *et al* (1959) and Gernandt & Gilman (1960) parts of the cerebellum have an inhibitory action in the vestibular system This inhibition is characterized by Gernandt & Gilman as a tonic control of labyrinthine reflexes, and these authors claim that such a control is effected also by the medial (midline bulbar) reticular formation

Halstead (1935) and Halstead *et al* (1937) found in pigeons that the postrotatory nystagmus increased in duration when parts of the cerebellum were damaged However habituation to repeated identical stimuli was not eliminated and moreover the habituation curves were approximately parallel in the operated animals and in their controls

These authors maintained that their results demonstrated that the mechanism of habituation was influenced by the cerebellar lesion A criticism of this conclusion may be in place (1) The fact that habituation still occurred after the cerebellar lesion and furthermore that the habituation curves were parallel should have led to a preliminary assumption that the lesion had no effect at all on habituation but the authors did not discuss this hypothesis (2) No reason was given for their method of measuring the magnitude of habituation

Dow & Moruzzi (1958) criticized the authors for the inexact method they used in performing the cerebellar lesion, but this criticism is of minor significance since it is *quite evident from the results that the vestibular parts of the cerebellum* had been damaged by the operation In this connexion I should like to quote a comprehensive view on cerebellar physiology expressed by Dow & Moruzzi (p 372) The fundamental idea is that the cerebellum acts as an energizer, keeping up a certain level of activity in the spinal cord in the brain stem and in the cerebrum It would remain for extracerebellar mechanisms to modulate this background according to the needs of the body

Thus there are biological reasons for believing that destruction of the vestibular parts of the cerebellum does not influence the process of habituation Statistical reasons for this opinion will be given later in the present paper

Bard *et al* (1947) and Wang & Chinn (1956) showed in dogs that destruction of certain parts of the cerebellum (the nodulus and to some extent also the uvula) caused an increase in the resistance to stimuli which *before the* operation were very effective in causing motion sickness This is astonishing since the operation is known to effect a release of the tonic control of labyrinthine reflexes in some animal species (pigeons rabbits cats rhesus monkeys) Thus it would seem that some other cerebellar mechanism is involved in motion sickness

It is a delicate task to apply the results obtained from animal experiments to a discussion on motion sickness in man Nevertheless it may be concluded from these experiments that the results do not support the hypothesis that insufficient cerebellar control of the labyrinthine reflexes is of any importance in developing motion sickness in man

The subjects who were selected for habituation experiments in the present study may not be representative for their respective groups as a whole The

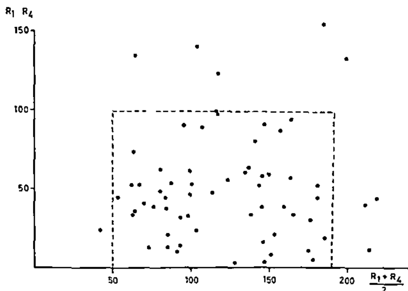


FIG 3 Relation between difference in intensity and mean intensity of nystagmus responses to repeated identical stimuli R_1 (R_4) The first (last) response (number of nystagmic beats) to a series of four identical stimuli No uniform tendency towards increase or decrease in difference ($R_1 - R_4$) can be seen with mean intensity level (($R_1 + R_4$)/2) The points are rather diffusely located within the central area of the diagram (The borders of the central area are indicated by broken line)

selection was regarded as inevitable, however, and was made without taking into consideration which group the subjects belonged to

Now the question is whether the subjects in Group B showed a less pronounced ability to habituate than the subjects in Group A The answer to this question requires a suitable measure for the magnitude of the habituation Therefore, a larger material (illustrated in Fig 3) was selected and treated in the same way as the subjects in the present study There was no correlation ($r = 0\ 07$) between the intra individual difference and mean intensity, computed for the first and the last response in each series of four identical caloric stimuli Hence the difference (expressed in an absolute value) seems to be a suitable measure for the magnitude of the habituation This also means that the magnitude of the habituation ought not to be indicated as a relative, e g percentual decrease

Using the absolute value for the difference as a measure of the magnitude of the habituation it may be concluded that the habituation was approximately equal in Groups A and B (the habituation curves were approximately parallel as is seen in Figs 1 and 2)

Since it seems reasonable to assume that the magnitude of the transfer of the habituation is directly proportional to the magnitude of the habituation to identical stimuli, it seems natural to believe that the group difference in response intensity at the routine caloric test was not due to a difference in the magnitude of the transfer of habituation from physiological to experimental labyrinthine stimulation

On the basis of the present results it is of course, not justified to conclude that the process of habituation is without importance in motion sickness. However probably only 1 to 5 per cent of the general population are entirely unable to habituate themselves to the stimuli of motion sickness (Noble 1948, Tyler & Bard 1949). Naturally, such individuals only exceptionally become seamen and there is no representative of this category amongst the subjects who participated in the present investigation. They all reported that they were readily able to recover from motion sickness if it ever occurred.

The material investigated did not contain any case of pronounced sensitization but the significance of sensitization in the development of motion sickness should be pointed out here. As was already observed by van Wulfften Palthe (1922) progressive increase in response intensity to repeated rotatory tests was an ominous sign that the next flight might cause motion sickness. Zwerling (1947) provoked motion sickness by means of rotatory stimuli and was able to cause an enhanced tendency to motion sickness by administering repeated electric shocks to the subjects during the rotations. He advanced the hypothesis that anxiety in the experimental situation brought about the increased tendency to motion sickness in that particular situation. Now it is known (see Lidvall in press) that dishabituation—and sensitization—to repeated labyrinthine stimulations can be effected by alerting (arousal), which seems to afford a natural explanation for Zwerling's observations.

Zwerling found a slight, statistically non significant, positive correlation between neurotic tendency (as measured by the MMPI a questionnaire) and the tendency to motion sickness. In the present investigation there was no difference between the two groups as to the loading of neurotic anxiety, but this must not be interpreted to mean that neurotic anxiety is entirely without importance in the occurrence and persistence of motion sickness. This problem will be discussed in a study which is in the course of completion.

Thus, of the vestibular mechanisms considered in this discussion, it seems more likely that the group difference in response intensity to the routine caloric test is due to a group difference in the (primary) labyrinthine sensitivity rather than to group differences in cerebellar inhibition or transfer of habituation from physiological to experimental stimulation.

ZUSAMMENFASSUNG

Bei der kalorischen Routineprufung waren die Vertigo- und die Nystagmus-Reaktionen durchschnittlich schwacher in einer Gruppe von Seeleuten, die behaupteten, dass sie praktisch niemals eine Seekrankheit erlitten hatten, als in einer Gruppe von Seeleuten, die sagten, sie seien von Seekrankheit ab und zu betroffen.

Die Versuchspersonen, die bei der kalorischen Routineprüfung deutliche Vertigo- und normale Nystagmus-Reaktionen hatten, wurden fur ein Studium der Reaktionen auf wiederholte identische monolabyrinthare kalorische Reizungen ausgewahlt. In beiden Gruppen traf Gewohnung ein, sowohl in der Vertigo- wie in den Nystagmus-Reaktionen, und die Gewöhnungskurven verliefen beinahe parallel.

Die vestibularen Mechanismen, die als bedeutend fur die Entstehung und das Andauern der Seekrankheit aufgefasst werden, werden diskutiert. Als Schluss wird behauptet, der Unterschied zwischen den Gruppen in der Intensitat der Reaktionen auf der kalorischen Routineprufung sei von einem Unterschied in der Empfindlichkeit der labyrintharen Sinnesorgane abhangig.

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THE OTOTOXIC EFFECT OF KANAMYCIN

A Clinical and Histological Study

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A patient with chronic pyelonephritis and uremia was treated with Kanamycin, 1 g daily for 11 days. This treatment caused grave damage to the internal ear, manifesting itself by complete deafness of both ears as well as abolished caloric reaction of the right ear and reduced caloric reaction of the left. Subsequent histological examination of the temporal bones revealed degeneration of the neuroepithelial hair cells everywhere in the internal ear, though chiefly in the basal part of the organ of Corti. The case demonstrates the great risk involved in the Kanamycin treatment of patients with impaired renal function. This risk must be supposed to be increased if the patient has been treated previously with streptomycin or dihydrostreptomycin.

Numerous clinical and physiological investigations are available which aim at throwing light on the toxic action of Kanamycin on the eighth cranial nerve (Finland, 1958, Everberg 1959, Rotwitt Schmidt, 1959).

The ototoxic effect seems in general to depend more on the total amount of Kanamycin given than on the mode of dosing, though the sensitivity to the drug varies considerably from one patient to another. Great caution must be exercised in patients with impaired renal function. In such patients the consequent very high serum levels of Kanamycin may cause severe and irreparable damage of the acoustic and, in rarer cases, also the vestibular apparatus.

The number available of histological examinations with a view to showing which structures in the internal ear and the eighth cranial nerve are the most directly affected by the ototoxic effect of Kanamycin is much smaller.

Hawkins (1959), in experiments on cats, showed that the primary action was aimed at the organ of Corti, presumably the hair cells, but that degeneration of ganglion cells and nerve fibres was seen, too, in a few cases.

In guinea pigs Ward & Fernandez (1961) localized the main point of attack in the outer hair cells, especially in the basal part of the cochlea.

Benitez, Schuknecht & Brandenburg (1962) recently published the results of careful histological examinations of the temporal bones of two patients who had lost hearing after Kanamycin treatment. Degenerative changes were demonstrated in the organ of Corti, most pronounced in the basal turn. The

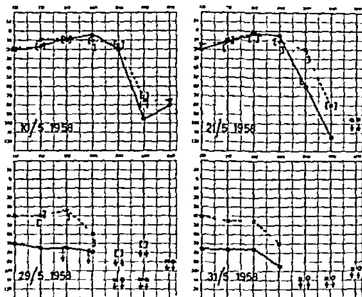


FIG 1 Audiograms showing the ototoxic effect of Kanamycin treatment on patient with chronic pyelonephritis and uraemia Kanamycin given May 11 21, 1958 a total of 11 g Audiometry and tests with Bárány's noise box on June 3, 7, 11, and 30, as well as Aug 9, 1958 showed complete deafness of both ears

mildest changes consisted in loss of outer hair cells followed by loss of inner hair cells, and in the severest degree also of supporting cells

Present Investigations

In a patient kept under close observation by repeated acoustic vestibular tests before during and after Kanamycin treatment we found similar changes on subsequent histological examination of the temporal bones in the internal ear We have therefore thought it of interest to publish this case

The patient was a blacksmith, aged 30, whose ears had for several years been exposed to much noise, and who had been suffering from chronic pyelonephritis for about 15 years He had been in hospital several times before his present admission and treated with different antibiotics, including streptomycin 1 g b i d from Feb 20 to Feb 24, 1958, and duostreptomycin 1 g b i d from April 26 to April 29 1958 with no subjective influence on the hearing or the vestibular function

Owing to severe uremia and highly resistant bacteriuria, treatment with kanamycin ½ g b i d was started on May 11, 1958 and at the same time control was commenced of the acoustic vestibular functions On May 18 the patient complained of excessive bilateral tinnitus As audiometry on May 21 revealed incipient deafness to high tones, the Kanamycin treatment was immediately discontinued The tinnitus persisted in spite of this, and hearing declined until complete deafness of both ears on June 3 A total of 11 g Kanamycin had been given Fig 1 illustrates the progression of the patient's

TABLE 1 *Development of acoustic vestibular symptoms in relation to Kanamycin treatment as well as serum Kanamycin activity and serum creatinine level in patient with chronic pyelonephritis and uremia*

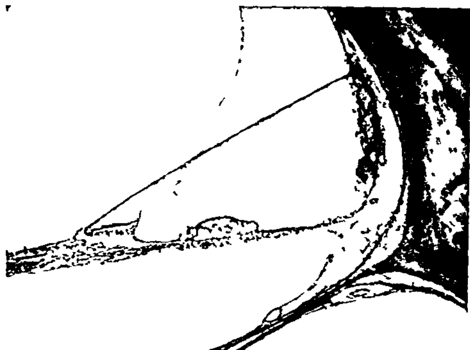
Date	Kanamycin treatment	μg Kanamycin per ml serum	Serum creatinine mg %	Tinnitus	Vertigo	Caloric reaction Right side	Left side
May 9			11.2				
10						normal	normal
11							
11							
13							
14			11.6				
15							
16	½ g × 2	100					
17		140					
18		120		+ + +			
19		130	11.3	+ + +			
20		160		+ + +			
21		180		+ + +			
22		200	12.5	+ + +			
23		165		+ + +			
27		95	12.6	+ + +			
29				+ + +		reduced	normal
June 7				+ + +		reduced	normal
9		6	12.6	+ + +			
11				+ + +		absent	normal
20			13.5	+ + +	+		
July 11			13.0	+ + +	+		
Aug 9				+ + +		absent	reduced

loss of hearing. Before the patient had become completely deaf, examination for recruitment using partly Fowler's method and partly Metz' method for testing the acoustic impedance of the ear showed that the affection causing impairment of hearing was localised in the cochlea.

On June 7 reduced caloric reaction of the right ear was demonstrated and on June 11 abolished reaction of this ear. For some days about June 21 the patient was transitorily dizzy with nausea and vomiting. On Aug. 9 reduced caloric reaction of the left ear was noticed in addition to the abolished reaction of the right. At no point of time did we see spontaneous or positional nystagmus.

The patient's renal disease was progressive during the entire observation period. The progression manifested itself by increasing uremia and rising serum creatinine values. He died peacefully on Aug. 29, 1958.

Table 1 illustrates the development of acoustic vestibular symptoms in relation to the Kanamycin treatment as well as the serum Kanamycin activity and serum creatinine level.



Figs. 2–6. Kanamycin intoxication in the cochlea. Mag. ×64. Haematoxylin–eosin.

Fig. 2. Left cochlea, apical turn.

About 6 hr after death 10 % formalin was injected into the middle ears through the tympanic membrane. Subsequently the temporal bones were fixed in 10 % formalin.

On histological examination almost identical changes were found in both internal ears. In the organs of Corti complete loss of inner and outer hair cells was seen in the basal and middle turns, whereas a small number of hair cells was found here and there in the apical turn. Correspondingly, loss of supporting cells and collapse of the organ of Corti were observed in the basal part of the cochlea, whereas the configuration of the organ of Corti was well preserved in the apical part (Figs. 2–5).

The spiral ganglion was found to be well preserved in the apical turn, whereas the basal turn presented a fall in cell number and suggestion of glial proliferation without degenerative changes being observed in the sensory cells themselves (Fig. 6). The number of nerve fibres was not reduced in the lamina spiralis, nor more centrally in the acoustic nerve. The tectorial membrane as well as Reissner's membrane were normal. An albuminous exudate was found in the vestibular and the tympanic scalae, a phenomenon often seen in uremics.

All in all the changes were somewhat more pronounced in the right ear than in the left.

In the vestibular part of the labyrinth the membranous labyrinth was found to be of normal appearance and configuration. No distinct degenera-

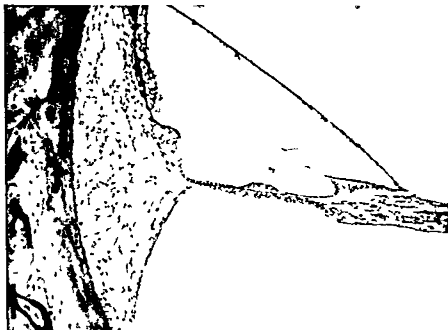


Fig. 3. Left cochlea, basal turn.



Fig. 4. Right cochlea, apical turn.



Fig 5 Right cochlea basal turn

tive changes were seen of the cells in the neuroepithelium of the cristae and maculae though the number of hair cells was judged to be considerably reduced everywhere As for the maculae sacculi a marked difference was noticed between the two sides the number of hair cells being considerably smaller on the right side than on the left The vestibular nerve and Scarpa s ganglion displayed no unquestionable degenerative changes

The tympanic membrane the tympanic cave and the ossicles were normal

Histological examination of the brain (Erna Christensen) revealed universal ganglion cell degeneration The changes were most conspicuous in the cortex and here perhaps a little more pronounced in the temporal lobe than in the remaining parts of the cortex as well as in the medial geniculate body Deiter s nucleus and the acoustic tubercle In the white substance there was seen in addition to the diffuse interfibrillar swelling a more pronounced swelling within an area of the left internal capsule and in the posterior longitudinal fascicula on both sides

Altogether the histological changes found suggested toxic damage of the brain tissue and of the blood brain barrier It was impossible to say which was affected first

Comments

Our case shows in agreement with the results of previous investigations how very toxic kanamycin may be to patients with an impaired renal function A total dose of no more than 11 g caused complete deafness of both ears and grave damage to the vestibular apparatus



Fig 6 Left spiral ganglion in basal turn

The particularly malignant course in our case was explainable both by the greatly impaired renal function and by the fact that he had been treated with streptomycin and dihydrostreptomycin shortly before the Kanamycin treatment The latter may have left the hair cells in a state of increased sensitivity This is a fact to which attention should be given in treatment with any streptomycin like antibiotic

The impaired hearing of high tones present before the Kanamycin treatment which we interpreted as due to working in noise may possibly have been provoked in part by the previous treatment with streptomycin and dihydrostreptomycin

The progression of the internal ear affection in spite of immediate discontinuation of the Kanamycin treatment is also a well known phenomenon It is explained as a result of irreversible changes in the hair cells but is also due to the long time elapsing before the greatly damaged kidneys can excrete the amount of Kanamycin accumulated in the organism

Kanamycin treatment much more rarely causes damage to the vestibular apparatus than to the cochlea In our patient this did not occur till 14 days after the cessation of treatment and at a time when the serum Kanamycin activity again approached zero The vestibular affection was also progressive to the point of extinct function on one side and a greatly reduced function on the other The same is known in cases of streptomycin treatment

The histological findings bear out the clinical observation that the toxic effect of Kanamycin on the eighth cranial nerve comprises primarily the hair

cells in the organ of Corti, whereas more rarely the hair cells of the neuro-epithelium of the cristae and maculae.

ZUSAMMENFASSUNG

Ein Patient bekam wegen einer chronischen Pyelonephritis mit Urämie 1 g Kanamycin täglich in 11 Tagen. Diese Behandlung verursachte eine schwere Beschädigung des inneren Ohres mit doppelseitigem, totalem Hörverlust, einer Erlöschung der kalorischen Reaktion auf der einen Seite und einer Herabsetzung derselben auf der anderen Seite. Die histologische Untersuchung der Felsenbeine zeigte überall eine Degeneration der Haarzellen, besonders doch im basalen Teile des Cortischen Organes. Der Fall zeigt das grosse Risiko, welches mit der Kanamycinbehandlung bei gestörter Nierenfunktion verbunden ist. Dieses Risiko ist als erhöht anzusehen, falls der Patient im voraus mit Streptomycin oder Dihydrostreptomycin behandelt wurde.

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HYPERNEPHROMA METASTASES IN THE EAR AND NOSE REGION

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The author describes two cases of metastasis from a renal carcinoma to the flat bones of the skull and to the nasal sinuses respectively A short account is given of the histologic picture of the primary tumour, followed by a discussion of the significance of this for prognosis and therapy The more adequate term ' renal carcinoma should be substituted for the old concept of hypernephroma

During recent years a few cases of hypernephroma metastases have been described in the ear, nose and throat region but they have been so infrequent that each fresh case deserves to be mentioned According to the survey of the literature made by Eneroth Martensson & Thulin (1961) hitherto only some 20 cases of metastases from hypernephroma in the nasal sinuses have been reported These authors suggest however, that hypernephroma metastases in the ear nose and throat region are more common than has so far been observed and the cases referred to in this article may also be added to those reported

The clinical data and pathology of the original tumour will not be dealt with in detail here with the reservation that the old term of hypernephroma be entirely abandoned and replaced by renal carcinoma

From a histologic point of view two types of tumour can be distinguished in this group one consisting of large cells of the so called clear cell type and the other of small polymorphous cells sometimes exhibiting a papillomatous tumour formation (Figs 1 and 2 respectively) Many authors consider that these forms represent only various degrees in the differentiation of renal carcinoma As a rule the histologic picture is found to vary within the same tumour but one type of cell is predominant In general the clear cell type of tumour is considered to have a more favourable prognosis as well as being more sensitive to radiation (Foot & Humphreys 1948 Bottiger & Ivemark 1959)

The time between the detection and possibly the treatment of the primary tumour and the appearance of the metastases varies to a very considerable extent and often this period is extremely long More frequently than in the case of other malignant tumours metastases from renal carcinoma make their appearance as solitary tumours On the other hand it is not altogether unusual for the metastatic tumour to be the neoplasm which is first diagnosed

cells in the organ of Corti, whereas more rarely the hair-cells of the neuro epithelium of the cristae and maculae

ZUSAMMENFASSUNG

Ein Patient bekam wegen einer chronischen Pyelonephritis mit Urämie 1 g Kanamycin täglich in 11 Tagen Diese Behandlung verursachte eine schwere Beschädigung des inneren Ohres mit doppelseitigem, totalem Hörverlust, einer Erlöschung der kalorischen Reaktion auf der einen Seite und einer Herabsetzung derselben auf der anderen Seite Die histologische Untersuchung der Felsenbeine zeigte überall eine Degeneration der Haarzellen, besonders doch im basalen Teile des Cortischen Organes Der Fall zeigt das grosse Risiko, welches mit der Kanamycinbehandlung bei gestörter Nierenfunktion verbunden ist Dieses Risiko ist als erhöht anzusehen, falls der Patient im voraus mit Streptomycin oder Dihydrostreptomycin behandelt wurde

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Fig 2 Renal carcinoma undifferentiated type

of renal carcinoma metastases were recently treated One of them could almost be classified as a classic case of localization in the nasal sinuses its symptomatology corresponded to that of the cases published by Eneroth *et al* (1961) On the other hand our second case displayed quite a different symptom picture and localization of metastases and belonged moreover to those cases where the primary tumour is diagnosed only subsequently

Case Reports

Case 1 —A 66 year old retired accountant previously healthy Admitted to the department on account of trouble with his left ear for 2 3 months it had felt as if it were stopped up and there was buzzing in the ear of the type that is synchronous with the pulse beat Some months before admission he noticed a slight swelling at the back of his left ear about that time he had experienced difficulty in closing his left eye and the left corner of his mouth was slightly askew Tired Lost 6 7 kg in weight No difficulty in urinating State general condition unaffected Left sided peripheral facial paresis Blood pressure 160/95 Heart, lungs normal physically Ear nose and throat normal A soft swelling of a doughy consistency at the back of the left ear covering an area of about 3 4 cm Vesicular murmur synchronous with the pulse was audible here Urine normal ESR 53 mm/t Audiogram moderate conduction loss in the left ear (Fig 3) Eyegrounds normal X rays the skull showed damage the size of the palm of a hand in the occipital bone and the temporal bone

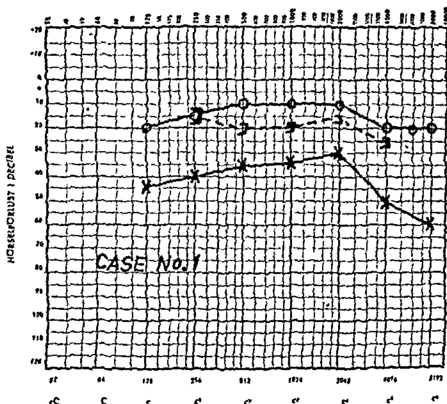


Fig 3 Audiogram Case No 1

with the mastoid process (Figs 4 and 5), in the lungs there were a number of ball-shaped infiltrations the size of walnuts Urography showed an expansive process in the lower part of the left kidney Renal aortography rounded tumour, the size of a mandarine, rich in pathological vessels

In view of the diagnosis of renal carcinoma the patient was transferred to the Department of Surgery, where a left sided nephrectomy was performed The finding at operation and the histologic examination of the surgical specimen confirmed the diagnosis The histologic picture revealed a tumour mainly undifferentiated and composed of small cells (Fig 2) The postoperative course was uneventful, but no effect was produced on either the facial paresis or the noise in the ears There was a gradual, increasing deterioration in the patient's general condition

Case 2—A 53 year old foreman Previously healthy Ten months before admission to the Department of Otolaryngology, a left sided nephrectomy had been performed at another hospital on account of renal carcinoma Microscopic examination showed clear-cell type The patient was admitted to the Department of Otolaryngology on account of profuse epistaxis which was very difficult to arrest Anterior rhinoscopy disclosed medial displacement of the left nasal wall of the maxillary sinus and a distention under the inferior turbinate Posterior rhinoscopy revealed edematous mucous membrane Oral cavity inflation of left half of the palate comprising mainly the hard palate Drum membrane was normal Urine status normal ESR 18 mm/t X ray examination of the nasal sinuses including tomography compact density of



FIG 4



FIG 5

FIGS 4 and 5 Damage to the occipital and [illegible]



FIG 6 Density of the left nasal cavity and destruction in the wall of the left maxillary sinus Case No 2

the soft parts of the left nasal cavity maxillary sinus ethmoidal cells and sphenoid sinus Widespread bone damage in the medial left wall of the maxillary sinus and in the base of the nasal cavity The lateral wall of the maxillary sinus was partly destroyed Bone damage in the medial part of the left orbital floor and in the ethmoidal cell region The pterygoid process appeared to be intact (Fig 6) Biopsy from the maxillary sinus in accordance with the Luc Caldwell technique disclosed a large tumour with the same histologic picture as that of the operative preparation from the former renal operation i e a renal carcinoma of the clear cell type (Fig 1)

Since a complete examination of the patient with X ray examination of the skeleton and the lungs and intravenous urography did not reveal any further metastases or signs of the remaining kidney being involved we considered that we were justified not only in regarding this metastasis localized in the sinuses as a solitary metastasis but also in performing a radical operation on the left sinus process The operation was performed after the ligation of the external carotid artery as a coagulation of a malignant maxillary tumour The postoperative course was normal and the histologic examination of the resection preparation showed good radicality

Case 1 is of special interest to the otologist not so much purely from the point of view of the tumour but rather as an example of the possible cause of tinnitus The case illustrates also the insidious asymptomatic course often observed in renal carcinoma until the effects of the metastases and the general tumour become manifest

In the Department of Otolaryngology we are overwhelmed with patients

seeking relief from tinnitus in the ears but it is very rarely that this can be objectively registered In reports on objective tinnitus it is stated that it is mainly attributable to vascular malformations or diseases and sometimes also to tumours localized in the meninges To these may now be added on the basis of the observations made the occurrence of a metastatic renal carcinoma in the temporal bone

Naturally this metastasis is not accessible to therapy but according to several authors including Ljunggren *et al* (1959) lung metastases have been known to disappear after nephrectomy Accordingly this operation was performed in the hope that even if it did not cause the large metastases to disappear it would nevertheless prevent their further growth From a histologic point of view this tumour belongs to a mixed form comprising the clear cell type and the papillomatous type which implies that prognostically it is classified as belonging to the more malignant group

Contrary to this more malignant type of tumour Case 2 represents the clear type of renal carcinoma with large cells and consequently it could be expected to have a better prognosis As has already been mentioned the case is entirely in conformity with those described by Eneroth *et al* (1961) and like them it was treated at the Department of Otolaryngology on account of profuse epistaxis which was difficult to control

Since after very careful examination no signs of any further metastases could be observed and in view of the fact that renal carcinoma is often characterized by a solitary metastasis it was considered that here surgical extirpation of the tumorous region was indicated

ZUSAMMENFASSUNG

Zwei Fallen von Nierentumorenmetastasen zu den Nebenhöhlen der Nase bzw zum Schlafenbein werden besprochen Der primare Tumor soll nicht mehr als Hypernephrom bezeichnet werden sondern lieber als Nierencarcinom Der histologische Befund des Nierencarcinoms kann eine gewisse Leitung in prognostischer und therapeutischer Hinsicht geben Metastasen von Nierencarcinomen sind wahrscheinlich in der Nebenhohlen nicht so selten vorkommen wie fruher beobachtet wurde Schlafenbeinmetastasen dagegen sind wahrscheinlich selten vorkommend aber konnen in gewissen Fallen Anlass zu Ohrensausen sein

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RECOVERY FROM TEMPORARY THRESHOLD SHIFT[1]

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This study reports work in which recovery from Temporary Threshold Shift (TTS) was studied by measuring the time taken for the elevated threshold to recover to normality (i.e. the latent time). It was found that with stimulus frequencies of 1000 and 2000 cps latent time increases as the stimulus intensity is raised from 20 to 60 db, decreases as the stimulus intensity is raised from 60 to 80 db and possibly increases as the stimulus intensity is increased from 80 to 90 db. With 4000 and 8000 cps stimulus frequencies it was found that there is a gradual negatively accelerating increase in latent time with increasing stimulus intensities. Latent times were found to be maximum at 4000 cps and minimum at 1000 cps and increases in latent time at 4000 and 8000 cps paralleled each other. It is suggested that the results offer indirect evidence that recovery from TTS is diphasic. The author suggests an explanation for the phenomenon based on facilitatory effects within the cochlea.

Temporary Threshold Shift (TTS) is normally measured operationally by taking the difference between the "normal" threshold and the threshold after sound stimulation for an individual subject. In this study TTS was measured by measuring the time taken for the elevated threshold to return to normality. Four subjects were stimulated by pure tones of frequency 1000, 2000, 4000 and 8000 cps at various intensities. The results are discussed in terms of their implications for the phenomenon of diphasic recovery from TTS.

During the past decade there has been a great deal of controversy over the temporal course of recovery from Temporary Threshold Shift (TTS). It has been suggested that recovery from TTS consists of two phases, i.e. is diphasic (Hirsh & Ward 1952, Hirsh & Bilger 1955, Jerger 1956). However, other workers (Hood 1950, Harris 1953, Epstein & Schubert 1956) have disagreed.

In all of the work published on this controversy the normal operational measure of TTS has been used. This consists of measuring the difference between the threshold for an individual subject at a given time after the cessation of the stimulus tone and his threshold as measured under "normal" pre-stimulus conditions. Moreover, in the majority of experiments dealing with this phenomenon the method of Békésy audiometry (see Békésy

... blished expe

reliability of

threshold measu ... ed to record

[1] This research was carried out by the author at the University of Durham, England.

auditory thresholds at a single frequency for long periods of time Consequently it was felt that some of the controversial results on diphasic recovery might stem from the use of this method In the experiments on diphasic recovery consideration is only given to the general shape of the temporal recovery curve i e of threshold elevation as a function of time from cessation of the stimulus tone without any emphasis on *when* the threshold returns to normality Thus the author felt that some light might be thrown on the controversy if instead of using threshold elevation as a measure of TTS some other measure could be found The measure chosen was the time taken for *the elevated threshold to return to normality* and in the experiments reported this measure of TTS was used It will subsequently be referred to as the latent time (see Rodda 1960)

Experimental Design

Apparatus

The basic circuit consisted of a frequency source (audio tester) an attenuator a three way switch a transformer and a standard earphone The output from the audiotester was fed into the attenuator and the output from this was in turn fed through the switch and the transformer into the standard earphone

The audio tester was a Marconi (Type T F 894A) calibrated from 50 cps to 27 k/cps and designed to work to a 600 15 and 3 ohm output The frequencies are accurate to $\pm 2\% \pm 5\%$ cps when the instrument has reached thermal equilibrium and the output distortion is 1 5% of the total at 1 5 watts and 2% of the total at 2 watts when the frequencies are between 100 and 8000 cps The audio tester is itself capable of 50 db attenuation The attenuator in the circuit was used to extend this range and was an Advance Low Frequency Attenuator (Type A 64) having an input and output impedance of 600 ohms and giving 70 db attenuation in 1 db steps The standard earphone is manufactured by Standard Telephones and Cables Ltd and has a specification Type 4026A head receiver It is a moving coil type of instrument with a frequency response of 50 cps to 10 k/cps The earphone was calibrated at the National Physical Laboratory Teddington and the response of the earphone at standard frequencies in decibels above 1 dyne per square cm per volt are given It was not possible to cushion the standard earphone because of interference with the calibration but the dummy earphone on the other side of the headband was cushioned to provide reduction in intensity of external noises and also to make the headphone more comfortable to wear The impedance of the earphone is approximately 25 ohms at 1000 cps Therefore a transformer with an input impedance of 600 ohms and an output impedance of approximately 25 ohms was incorporated in the circuit The three way switch was used to short the transformer out of the circuit when no input was being passed through the earphone This avoided the presence of noise in the earphone due to induced currents

Procedure

After standardization of the earphone the following procedure was used in each test session (i) a threshold measurement in which the threshold for a pure tone was determined monaurally using a hundred percent response criterion (ii) a stimulus period in which the pure tone was applied monaurally to the ear of the subject (iii) a fatigue measurement in which the latent time necessary for the threshold for the pure tone to return to the value determined in (i) was recorded In any one experimental trial the same pure tone was used in parts (i) (ii) and (iii) of the procedure i e the stimulus and test tones were the same frequency

The threshold as determined in (i) was always determined in an upward direction The intensity of the tone was adjusted to about 20 db below the threshold for the subject being tested The tone was pulsed by means of the three way switch and its intensity was increased in 1 db steps until the subject responded to ten consecutive applications of the tone at a given intensity The intensity of the tone at this point was taken as a measure of the subject s threshold During the second part of the test period the tone was continuously applied to the ear of the subject for one minute At the end of one minute the tone was cut off and its intensity adjusted to the threshold value determined in (i) During the third part of the test period the tone at threshold intensity was again pulsed and applied to the ear of the subject The time from the end of the second part of the test period to the subject s first response to the tone when applied at threshold value was noted This gave a measure of the latent time However in order to work to the hundred percent threshold criterion the tone was applied to the ear for a further period following his response to it If he failed to respond to the ten consecutive applications of the tone following his first response the result was discarded and the trial repeated later in the experimental period

Frequencies of 1000 2000 4000 and 8000 cps were used in the experiment Each frequency was tested in turn but the order of testing was randomized for the different subjects Half the subjects were tested on the right ear and half on the left ear The intensity of the tone during the stimulus period was varied from 10 to 110 db re the individual subjects threshold in 10 db steps The actual physical intensities represented by these variations were from 18 1 to 100 8 db The procedure detailed above was repeated three times for each subject at each of the stimulus intensities Within each frequency the order of testing of the different intensities and the three separate tests at each intensity were randomized The mean of the three separate measures of latent time at each stimulus intensity gave a measure of the latent time for recovery of the threshold to normality at a given stimulus frequency and intensity

Subjects

Four subjects were used throughout the course of experiment All were first year undergraduate students of the department of Psychology in the

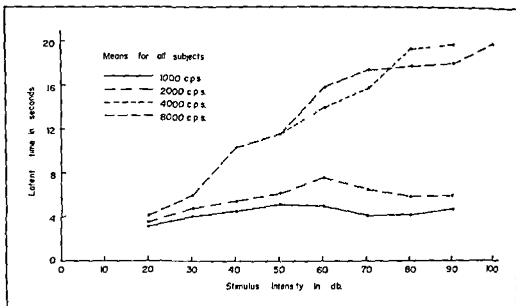


FIG 1 Shows the mean latent time (for all subjects) as a function of the intensity of the stimulus tone Parameter is the frequency of the stimulus tone

University of Durham, England Threshold measurements under normal conditions indicated that only one of the subjects suffered from any defect of hearing For the latter hearing for frequencies above 12 k/cps was virtually non existent

RESULTS

The mean latent time for recovery was calculated for the four subjects used in the experiment for each stimulus frequency and intensity tested at The results are illustrated in Fig 1 The stimulus intensity is plotted in terms of db re 0 0002 dynes/cm² rather than in terms of db re the individual subjects threshold in order to equate the physical intensities for each subject Since individual thresholds vary this means that the points shown on the abscissa cover a small range of intensities For 1000 cps this range was 4 db, for 2000 cps the range was 2 db, for 4000 cps the range was 7 db and for 8000 cps the range was 3 db Thus for the individual subjects the stimulus intensity at 1000 cps (shown on the abscissa as 20 db re 0 0002 dynes/cm²) would in fact range from 18 1 to 22 1 db However, for each individual subject the intensity of the tone was increased in 10 db steps Since there is no overlap in the ranges covered the only effect this would have on the results is to widen the individual differences It would not affect the shape of the graphs or the general conclusions that can be drawn from the results

Inspection of Fig 1 gives rise to the following observations (i) At 1000 and 2000 cps there is a gradual increase in latent time as the stimulus intensity is increased from 20 db to approximately 60 db From 60 to 80 db there is

TABLE 1 *Analysis of variance of frequency intensity and replication relationships in recovery from TTS using data from four subjects*

F ratio is obtained by dividing variance estimate for intensity or replications by the error variance estimate

Frequency in cps	Intensity Variance estimate	Intensity *df*	Intensity *F* ratio	Replications Variance estimate	Replications *df*	Replications *F* ratio	Error Variance estimate	Error *df*
1000	1 328	7	27 669[a]	0 185	2	3 854[b]	0 048	14
2000	4 274	7	57 756[a]	0 055	2	0 743[b]	0 074	14
4000	94 128	8	290 518[a]	0 620	2	1 914[b]	0 324	16
8000	51 952	4	125 185[a]	0 640	2	1 542[b]	0 415	8

[a] Highly significant at 1 % level of confidence
[b] Not significant

a gradual decrease in latent time There is possibly a slight increase in latent time between 80 and 90 db (ii) At 4000 and 8000 cps there is a gradual negatively accelerating increase in latent time with stimulus intensity, (iii) The latent time is maximum at 4000 or 8000 cps and is minimum at 1000 cps Because of the small differences in latent time in Fig 1 it was decided to test the significance of the changes involved statistically To do this the original three measurements used in calculating the individual subject means were utilized The analysis follows that described by Lindquist (1953 p 197) for ' The Special Case of Simple Replications For each individual frequency a table was drawn up with replications 1, 2 and 3 as rows and the stimulus intensities as columns In the body of the table was placed the mean latent time for all the subjects on the first second and third replication at the given intensities Between column between row and error variances were calculated and the significance of the column and row differences determined The results of the analysis are summarized in Table 1

It can be seen from Table 1 that at each of the four frequencies used in the experiment the mean stimulus intensity differences in latent time are highly significant at the 1 % level of confidence It can also be seen from Table 1 that the differences in latent time associated with replication differences are not significant Since the subjects were given considerable practice prior to the experiment this is to be expected

Additional evidence for the relationships revealed in Fig 1 was obtained by applying a *t* test to the data used in the analysis of variance The method used [illegible] presented the [illegible] cps, out of 28 [illegible] significant at [illegible] 2000 cps out of 28 possible intensity differences in latent time only two were not significant at 4000 cps out of 32 possible intensity differences in latent

TABLE 2 *Results of a t test to determine the number of intensity differences in latent time significant at the 1 % and 5 % levels of confidence*

Data used was the same as that used in the analysis of variance summarized in Table 1

Frequency in cps	Diff required for signif		No of differences			
	At 0 05 level	At 0 01 level	Possible	Signif at 0 05 level	Signif at 0 01 level	Not signif
1000	0 383	0 533	28	6	17	5
2000	0 475	0 661	28	3	23	2
4000	0 980	1 356	36	1	32	3
8000	0 385	0 559	10	0	10	0

time only three were not significant and at 8000 cps out of 10 possible intensity differences in latent time zero were not significant This would seem to prove fairly conclusively that the intensity differences revealed in Fig 1 are significant

However, with five non significant differences at 1000 cps and three at 2000 cps it becomes important with reference to the peaks in the graphs at 60 db to consider where these differences lie Hence in Table 3 are presented the differences between successive means, i e between stimulus intensities of 20 and 30 db 30 and 40 db and so on

It can be seen from the table that the reduction in latent time between 60 and 70 db is significant at the 1 % level at both 1000 and 2000 cps the reduction between 70 and 80 db is significant at the 1 % level at 2000 cps and the increase between 80 and 90 db is significant at the 1 % level at 1000 cps Thus it would appear that the first observations itemised after inspection of the Fig 1 are reasonably justified Further inspection of Table 3 confirms

TABLE 3 *Analysis of the significance of the differences in latent time between successive stimulus intensities at the given frequencies*

Frequency	Difference between							
	20 30 db	30–40 db	40–50 db	50–60 db	60–70 db	70–80 db	80–90 db	90–100 db
1000	0 90[a]	0 77[a]	0 60[a]	0 17	0 83[a]	0 07[c]	0 50[a]	—
2000	1 18[a]	0 49[b]	1 16[a]	1 37[a]	−1 00[a]	−1 18[a]	0[c]	—
4000	1 87[a]	1 16[a]	1 36[b]	1 19[a]	1 46[a]	0 47[c]	0 29[c]	1 40[a]
8000	—	—	—	1 78[a]	2 15[b]	3 39[a]	2 37[a]	—

[a] Significant at 1 % level of confidence
[b] Significant at 5 % level of confidence
[c] Not significant

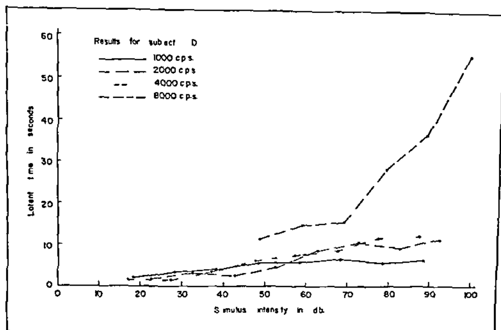


Fig 2 Shows the latent time as a function of the intensity of the tone Results for subject D Parameter is the frequency of the stimulus tone

the second observation The third observation must remain subjective since there is no way with the data available of testing its validity

In Fig 1 there does seem to be some confusion of the results in so far as the 4000 and 8000 cps line cross each other However this confusion was thought to arise from the results of one subject subject D The individual results for this subject are presented in Fig 2

Inspection of this figure reveals this subject showed only small increases in latent time as the stimulus intensity was increased at 4000 cps but very large increases at 8000 cps In Fig 3 are presented the mean results for the other three subjects used in the experiment It can be seen that in Fig 3 there is no crossing of the 4000 and 8000 cps lines

They do surprisingly tend to remain parallel to each other Apart from this difference the characteristics of the graphs shown in Fig 3 are qualitatively similar to those shown in Fig 1 The discrepancy might be associated with the fact that subject D was the subject for whom hearing above 12 k/cps was virtually non existent The subject did in fact complain of tinnitus after stimulation at 8000 cps and this may have resulted in his abnormal behaviour at this frequency

The results may be summarized by stating that observations (i) and (ii) made above after reference to Fig 1 (see p 00) remain as stated Observation (iii) is amended to state it would appear that for normal subjects the latent time is maximum at 4000 cps and is minimum at 1000 cps A fourth observation can be added which states that it would appear that for normal

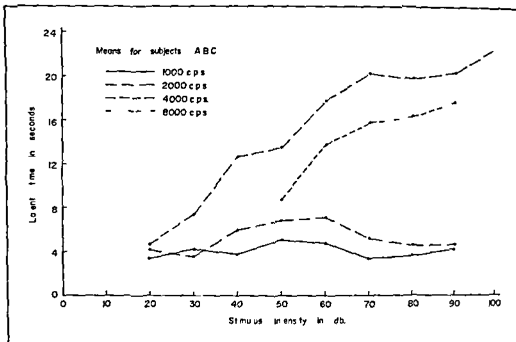


FIG 3 Shows the latent time as a function of the intensity of the stimulus tone Mean results for subjects A B and C Parameter is the frequency of the stimulus tone

subjects the increases in latent time with stimulus intensity at 4000 cps parallel those at 8000 cps

DISCUSSION

The parallelism between the 4000 and 8000 cps lines in Fig 2 is rather mystifying However, it does correspond with results obtained by Rodda (1962) on the relationship between TTS and the logarithm of the stimulus duration With a stimulus frequency of 1000 cps these experiments confirmed (see Hood op cit) that there is a linear relationship between TTS and the logarithm of the stimulus duration It was found that under certain conditions these linear increases with stimulus intensities of 70 90 and 110 db paralleled each other The significance of this parallelism is as yet unexplained but it may be an artifact of using intensity rather than loudness as the measure of stimulus magnitude

The results offer indirect evidence for the existence of diphasic recovery with stimulus frequencies of 1000 and 2000 cps since recovery from TTS at these frequencies is faster for stimulus intensities greater than 60 db than it is for stimulus intensities less than 60 db They offer no evidence for the existence of diphasic recovery with stimulus frequencies of 4000 and 8000 cps This latter statement is contrary to the results of Hirst & Ward (op cit and Hirsh & Bilger (op cit) who found diphasic recovery to be maximum at 4000 cps Since however these workers were concerned with bounce rather than the initial speed of recovery this may merely be a question of

emphasis of the various aspects of recovery from TTS The main importance of this indirect evidence is that without using Bekesy audiometry it confirms the general suggestion of the diphasic recovery experiments that initial recovery from TTS is quicker under certain conditions with stimulus intensities greater than 60 db than with stimulus intensities of less than 60 db

Explanation of the phenomenon is difficult However Hirsh & Bilger (op cit) suggest that it results from the additive effects of two recovery processes The first process they suggest is possibly a neural effect and the second process is possibly a biochemical effect The data of Hirsh & Ward would seem to raise one strong objection to this claim Hirsh & Ward claim bounce is maximum at 4000 cps but Hood (op cit) has shown that neural TTS effects are closely associated with equilibration and are maximum at stimulus frequencies of 1000 2000 and 3000 cps Hence one would expect diphasic recovery to be either maximum or minimum at these frequencies depending on the interaction between the neural and biochemical effects A second objection to the theory of Hirsh & Bilger is that it fails to take into account in any way the role of the cochlea in sound transmission

Bearing in mind the above objections the author (Rodda 1960) has proposed a theory based on facilitatory and inhibitory effects within the cochlea These effects it is postulated arise from a fatigue pattern (Gardner 1947) which remains within the organ of Corti after the cessation of the stimulus tone Such a theory based on cochlear effects would mean that neural effects at 1000 2000 and 3000 cps would not be expected The maximum at 4000 cps may be associated with the anatomical structure of the ear and Hilding (1953) has in fact suggested that there is a funnelling of sound on to this area of the cochlea The failure in recovery time to decrease with stimulus intensities greater than 60 db at 4000 cps may mean that at this frequency there is a decrease in the temporal range of the inhibitory effects but an increase in their magnitude This could be easily tested by measuring how long the subject hears the tone after the initial return to threshold value

ZUSAMMENFASSUNG

Die Arbeit berichtet von Untersuchungen über die Rückbildung von zeitweiliger Schwellenverschiebung (TTS) Ausgegangen wurde von der Zeit die die erhöhte Reizschwelle benötigt um den Normalzustand wiederherzustellen (d h Latenzzeit) Es zeigte sich dass die Latenzzeit bei Reizfrequenzen von 1000 und 2000 Hz zunimmt wenn die Reizintensität von 20 auf 60 db erhöht wird bei einer Erhöhung der Reiz intensität von 60 auf 80 db aber abnimmt und bei einer weiteren Erhöhung von 80 auf 90 db möglicherweise wieder zunimmt Bei Versuchen mit Reizfrequenzen von 4000 und 8000 Hz ergab sich bei zunehmenden Reizintensitäten eine fortschreitende negativ beschleunigte Zunahme der Latenzzeit Maximale Latenzzeiten wurden bei 4000 und minimale bei 1000 Hz beobachtet bei 4000 und 8000 Hz verlief die *Zunahme* der Latenzzeit parallel Die Ergebnisse könnten damit den indirekten Nachweis liefern dass die Rückbildung von TTS doppelphasig verläuft Die Erklärung für dieses Phänomen sieht der Autor in einer erhöhten Erregbarkeit des Nervs innerhalb der Cochlea

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